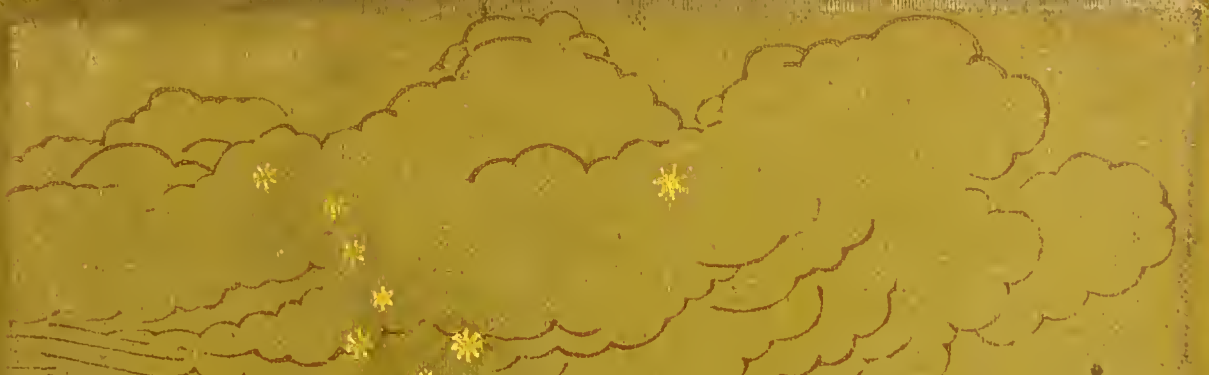

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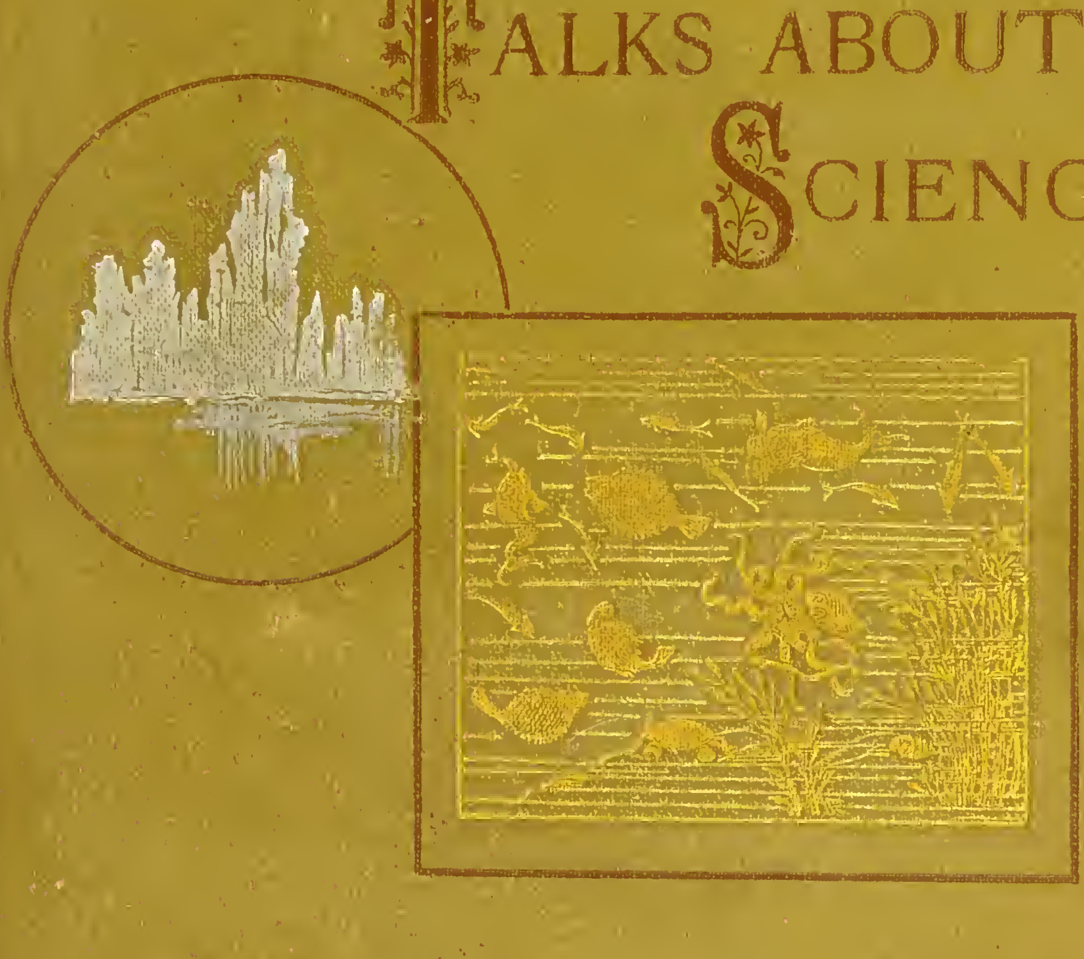
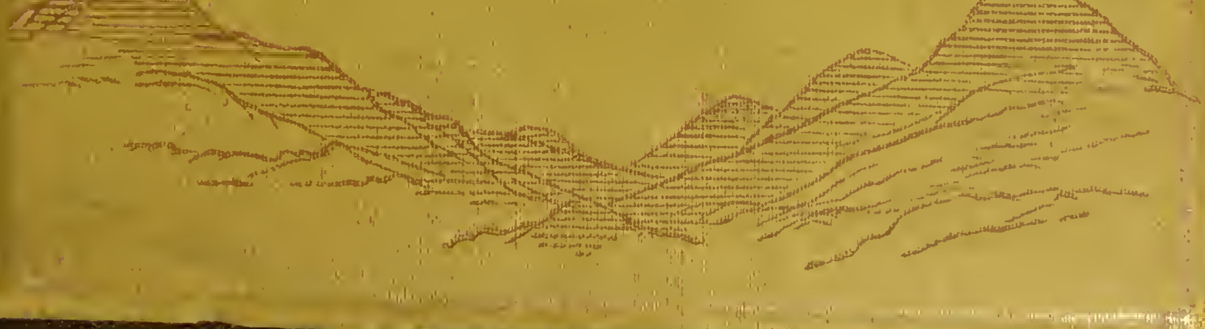


THOMAS DUNMAN



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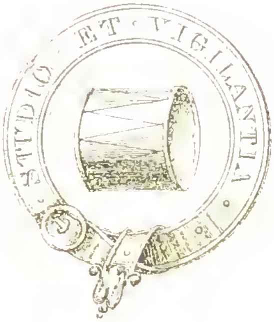

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TALKS ABOUT SCIENCE.

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Talks About Science

BY THE LATE

THOMAS DUNMAN,

FORMERLY LECTURER ON PHYSIOLOGY AT THE BIRKBECK INSTITUTION, AND
THE WORKING MEN'S COLLEGE.

WITH A BIOGRAPHICAL SKETCH

BY CHARLES WELSH.

GRIFFITH & FARRAN,
(SUCCESSORS TO NEWBERY AND HARRIS),
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BIOGRAPHICAL SKETCH.

THIS little volume has been prepared rather as a slight memento of one whose method of teaching endeared him to a wide circle of students of science than as containing any original contributions to the general knowledge of the subjects of which it treats.

The brief account of a too brief career with which it is prefaced is written, because it is felt worthy of being placed on record in some permanent manner, and also that it may serve in some degree both as an encouragement and a warning—as an encouragement, because it shows what may be achieved by energy and application; and as a warning, because it shows how surely and certainly Nature will be avenged, if from whatever cause her cautions are unheeded, and her laws ignored.

The Lectures here printed were delivered in various places during the past few years. The first four had been revised and published in pamphlet form; some of the others had been written out hastily for the use of the *Workmen's Hall Messenger*, a periodical published in connection with a Mission in Drury Lane, and others had been reported when delivered.

They are selected not because they represent the best of the work which Thomas Dunman did in his life-time—they certainly do not do this—but because they can be conveniently grouped under one title. There are other of his writings which doubtless possess more permanent value, but they are not available at present, as they are appearing at intervals in various serial publications. These will, however, give some idea of the extent of the field over which his studies ranged, and of the admirable power of popular exposition which he possessed. Like those of his great model, Professor Huxley, his lectures were never of the hard and dry nature which accords with the popular idea of a scientific discourse. They are enlivened by allusions to poetry and romance, and are full of living interest, while there are here and there flashes of quiet humour which won his audiences, and afford abundant explanation of his popularity with his students.

In listening to his lectures one was often reminded of what Lord Macaulay says of Sir James Mackintosh. His mind seemed to be a "magazine admirably arranged with everything in its place." "The article which you required was not only there. It was ready. It was in its own proper compartment. In a moment it was brought down, unpacked and displayed."

THOMAS DUNMAN was born on the 16th of December 1849. His parents were in the middle class of life, but owing to reverses of fortune they were only able to give him a very limited education. At an early age he left school and entered upon city life, but misfortunes attended him there, and he was obliged to relinquish it for an occupation much less congenial. But in whatever circumstances he found himself, his dearest companions were always his books, and the occupation of his leisure hours was ever the study of some branch of knowledge. In this way, and after leaving school, he learned French, Greek, and Latin, attained some proficiency in mathematics, and gained a considerable knowledge of physical science. In all this he was to a great extent, if not wholly, self-taught, and every penny that he could spare of his scanty earnings went to purchase books and materials. Meanwhile his reading in all departments of literature was wide but never superficial. Gifted with a remarkable memory, the acquisition of knowledge cost him little effort, and what he once learned he never forgot. He had a prodigious power of rapidly making himself acquainted with the contents of books, and could, like one of his favourite authors, Lord Macaulay, not only remember passages in volumes that he had not opened for years, but could describe accurately their position on the printed page.

While living in Hackney in 1869 he joined some classes in connection with the Science and Art Department, and from this time his education for what was to be the work of his life—the teaching of scientific subjects—may be said to have begun. Shortly after this, in 1871, he became clerk and book-keeper to a harness maker and currier in London—a post which was but poorly paid. There he worked amid surroundings that were neither pleasant nor congenial to one of his tastes and feelings, and though his duties were by no means light, he still continued to prosecute his studies at home. For he was now married, and a regular income, however small, was preferable to the uncertainty of his previous occupation. But he only undertook this work as a means to an end to enable him to live while he carried out his determination to qualify himself for some more useful and higher work in the world than the invoicing of harnesses and the pricing of stock in a currier's office. This latter work was, however, never neglected; he did it, as he did everything to which he put his hand, with conscientious thoroughness and efficiency. Although at this period he must often have felt himself like a race horse in the shafts of a farm waggon, he indulged in no vain sentiment, but manfully did his duty, hoping and believing that he would ultimately succeed in placing himself in a position where he could advantageously employ the powers which he could not but be conscious that he possessed.

It was about this time that he began to attend the classes at South Kensington, and in the three or four years following, he gained first-class certificates in the advanced stage in magnetism and electricity, acoustics, light and heat, and animal physiology. He also obtained certificates in practical and theoretical mechanics, steam, physical geography, geology, inorganic chemistry, practical plane and solid geometry, general biology, mathematics, physiography, and nautical astronomy. One of these certificates was accompanied by a very gratifying letter from Mr Norman Macleod, saying that he had been specially commended by the examiners, not only for the zeal with which he had worked, but for the ability which he showed. He also attended lectures and passed examinations in physics and practical physiology at the Royal School of Mines, and in the latter subject he headed the list of his year. This seems an enormous quantity of work to get through in such a time, and so it was; but it must be remembered that it represented, and was to a large extent the outcome, of his own private work and study of previous years.

It might here be remarked that whatever may be said of the results of the work done by the South Kensington system, Thomas Dunman was certainly not one of its failures. There was no "cramming" in his work; whatever the subject was he was never satisfied unless he could, wherever practicable, verify the facts experimentally for himself, and his subsequent remarkable successes as a teacher, of which more will be said later, proves his was no mere acquisition of superficial knowledge. As may be supposed, his strong love for the study of natural science received a powerful impetus from the teaching of Professor Huxley, who was to him a perfect model teacher of science, and upon whom to a great extent he formed his style.

His attendances at South Kensington during this period often necessitated absence from business during parts of the day, for which he had of course to make up at other times. He thus worked double tides in the most indefatigable manner, and it is due to his then employer to say that he was ever considerate in allowing him to divide his time in this way. No sooner had he gained the certificates qualifying him to take classes under the Science and Art Department than he set about finding work of this kind, and in several classes in the south of London, where he was then living, his work was much appreciated and brought successful results.

In 1874, through the introduction of Mr C. Kegan Paul, he undertook to teach classes in physiology and other subjects at the Working-Men's College in Great Ormond Street. Here was an institution which appealed peculiarly to his sympathies, and the value of which he could thoroughly appreciate. Self-taught in a large measure himself, it was his delight to find here a means of helping those who were contending with difficulties similar to those which he had had to encounter, and he at once threw himself with all his energy into the work of the place, and made his remarkable power as a teacher immediately felt. He inspired his pupils with enthusiasm for their subjects, won their personal attachment, attracted large numbers of new students, and gave such an impetus to that department of the college work as to create in effect a flourishing science school. It may be mentioned, as showing how thoroughly he was in sympathy with the spirit of the foundation of the Working-Men's College, that for some time, although it absorbed many precious hours every week, he refused all remuneration for his class-teaching, and only of late years consented to take a proportion of the class fees.

In 1877, on the retirement of Dr Aveling, he was appointed Professor of Physiology at the Birkbeck Institution, where the like success attended him in collecting and keeping about him large classes of eager students, while the practical results, both here and elsewhere, as shown by the examinations for which his pupils presented themselves, attested the thoroughness of his teaching. Subsequently he was appointed Professor of Animal Morphology at this institution, and he held both offices till his death.

These successes led the Society for the Extension of University Teaching to place him, in the winter of 1879, on their staff (although he had no university degree), as lecturer at an important London centre; and here his work bade fair to prove as valuable as it had elsewhere, but failing health interfered too soon with his labours in this quarter.

In the same year he published a very useful "Glossary of Biological, Anatomical, and Physiological Terms," which has been much appreciated by students both here and in America. About this time too he began to give popular lectures on scientific subjects in and around London, and at Chester, Rotherham, and other places, which were well appreciated. These are the lectures printed in this volume, but the printed page gives no idea of the remarkable ability he possessed as a lecturer. He spoke always without a single note, and his attractive style, his lucid exposition, and his strong personal enthusiasm in his subject, always carried his audiences along with him.

And now it seemed that at last the tide was beginning to turn which would bring him the fame and fortune to which he was, by his hard work and untiring industry, justly entitled. He had begun to find work for his pen, and contributed to Cassell's "Science for All," Ward & Lock's "Universal Instructor," "Amateur Work," and several other publications. This was an occupation which, perhaps next to teaching, he most enjoyed. And his pen was not only employed in the popular exposition of scientific subjects. He wrote several essays on literary and social matters. His style was fluent, and free, and pleasing, and he was a master of the art of putting difficult and abstruse subjects in attractive and simple language.

But all this work was gradually but surely undermining a constitution which, never strong, was eminently unfitted to bear so severe a strain as he was putting upon it. Towards the end of 1879 he broke down through overwork of the brain. A rest from the work of teaching and lecturing enabled him to rally to some extent, and to continue his work, to which, in spite of his weakness, he returned with all his old energy; and in the next year he prepared and published privately some valuable "Practical Notes for Students of Physiology," which are most thoroughly and carefully done. But he was, in January, 1882, prostrated by another attack, which from the first made his recovery hopeless, and he died on the 9th May, at the early age of 32 years, leaving a wife and two young children. He was buried in Ilford Cemetery, and his funeral was attended by a large number of his friends from the Working Men's College and elsewhere.

Thus was a career of great usefulness cut off by an early and untimely death; and many of us felt while he was being laid in his last resting-place—as one who knew him intimately has well said—"What a brave soul it was that inspired him to so much true, useful, and unselfish work. . . . His was a great nature in a frail body, and he, like so many more, never knew how to spare himself; but while with most men such overwork is for ends more or less selfish, in him it was work for the good of others."

Of his many good qualities of heart and character, I, who have known him in almost brotherly intimacy for the past thirteen years, hesitate to speak, lest I should sound too high a note of praise. The work he has done will be his best monument: there are numbers of men who will to the end of their lives feel the value of his thorough and earnest teaching, for influence such as he exercised, though not over a very wide field, or during many long years, cannot fail to bear good and useful fruit.

It is sad to think that in his young life he had known more care, trouble, and anxiety than most men of his age, but it was wonderful how his enthusiastic and sanguine spirit enabled him to bear and conquer his troubles. Time after time I have known him to receive in the battle of life what might be called a knock-down blow, but he has pluckily rallied, and braced himself anew for the fight. Faith and hope were ever strong in him, and although his scientific training had led him away from what is called orthodoxy, and he had "strayed under the shadow of condemned propositions," he never ranged himself with those who openly attack the strongholds of religious belief. I well remember when some years ago we made acquaintance together with the poems of William Cullen Bryant, he immediately adopted "Thanatopsis" as his favourite, and he often used to say that these, the concluding lines, exactly expressed his idea of how a brave and true man should meet his end :—

"So live, that when thy summons comes to join
The innumerable caravan that moves
To the pale realms of shade, where each shall take
His chamber in the silent halls of death,
Thou go not like the quarry-slave at night,
Scourged to his dungeon—but, sustained and soothed
By an unfaltering trust, approach thy grave
Like one who wraps the drapery of his couch
About him, and lies down to pleasant dreams."

So lived and so died Thomas Dunman.

My own part in this work is prompted by an affectionate desire to do honour to the memory of a dear companion, a true friend, one whom I in common with all who knew him held in the highest regard and esteem, and by the belief that many of those will like to possess this little memorial of his life and labours.

C. W.

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TALKS ABOUT SCIENCE.

I.

MECHANISM OF SENSATION.

IF we examine, even cursorily, the structure of any animal, except one of the very lowest order, we find that it consists of two sets of organs—one, the function of which is to carry on the various processes which pertain to that condition which we term Life; the other, which has for its object the supplying energy for the carrying on of the functions of the other set, and which regulates and controls the whole system. This latter set of organs is known collectively as the *Nervous System;* and in addition to the functions just mentioned, it serves as the *locale* of those which in the lower animals relate to consciousness and will, and which in man are connected with those higher powers which are variously denominated the Intellect, Mind, or Soul. It is with some of the functions of the Nervous System as developed in man that we have this evening to deal.

The Nervous System in man consists, first, of a collection of somewhat complicated structures, usually spoken of collectively as *the brain*, and occupying the cavity of the skull; secondly, of a somewhat cylindrical column of nerve-tissue, connected with the brain, and known as the *spinal cord*, be-

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ing lodged in a canal in the vertebral column, or spine; thirdly, of twelve pairs of nerves given off from the brain, and thirty-one pairs of nerves given off by the spinal cord; lastly, of a double chain of knots of nervous tissue, or, as they are termed, *ganglia*, connected with each other, and with the nerves of the brain and spinal cord by nervous cords, and also giving off nerves. The brain and spinal cord, together with the nerves given off from them, are, for convenience of description, usually grouped together under the term *the Cerebro-spinal System*, and the ganglia just referred to, together with certain others scattered over the system and termed "sporadic," are grouped together as *the Sympathetic System.* It must, however, be distinctly understood that these two systems are closely connected with each other, and are parts of one grand whole.

When we come to examine the structure of the Nervous System, we find that it is made up of two different kinds of nerve-tissue, one known as the *white* or *fibrous*, the other as the *gray* or *vesicular*. White or fibrous nerve-tissue is best seen in the nerves, which are wholly composed of it, and we will, therefore, briefly examine the structure of a nerve taken, we will suppose, from the cerebro-spinal system. If we take such a nerve, we find that it is encased in a membranous sheath (the *neurilemma*, or nerve-sheath), inside of which are a number of bundles, each bundle being made up of a number of fibres. From the outer sheath (*neurilemma*) of the nerve a number of processes are given off into the interior, and these passing between the bundles completely separate them from each other; if a transverse section of a nerve be taken, that is, if a slice be cut in the same way as a slice from a cucumber when cut for eating, the section will exhibit a number of small divisions, not unlike pigeon-holes, each containing a nerve-bundle. Each bundle, therefore, has a separate sheath, derived from the nerve-sheath, and each bundle, it is further seen, is made up of fibres, each separated from its neighbours in the same manner as the bundles are separated from each other; a bundle is in fact a nerve upon a small scale, and the same diagram will do either for a section of a nerve or of a nerve-bundle.

Coming to the structure of the fibres themselves, we find that each fibre consists of the following structures, viz., on the outside a sheath of delicate membrane, *the primitive sheath;* next to that, a sheath of white fatty matter, known as the *medulla* or *sheath of Schwann;* and in the centre a translucent thread, *the axis cylinder.* If the nerve-fibre be examined for some little distance, it is found that at intervals there are breaks in the sheath of Schwann, which sheath does not terminate abruptly, but gradually tapers until it ceases altogether for a short interval, and then we have only the axis cylinder and primitive sheath; these breaks in the sheath of Schwann are named, from their discoverer, *nodes of Ranvier.* The axis cylinder is continuous throughout the whole fibre, but the sheath of Schwann, besides becoming discontinuous at the nodes of Ranvier, disappears when the fibre reaches its place of final distribution, or when it enters the brain or spinal cord, that is to say, it is wanting at each end of the fibre. The fibres do not divide in the nerve or unite with other fibres, but only when the nerve is about to terminate in the tissues to which it is distributed, when it splits up into *fibrils,* a number of which sometimes mingle and form a kind of rough network, termed a *plexus.* Such is the structure of the great majority of the nerve-fibres of the Cerebro-spinal System, and their diameter varies from the $\frac{1}{12000}$th to the $\frac{1}{2000}$th of an inch. The great majority of the fibres found in the Sympathetic System are, however, much finer, and appear to consist of the axes cylinders only of the larger fibres just described. In the membranous sheath of nerve-fibres nuclei occur at intervals. From what we have just seen it appears that the axis cylinder is the only essential part of a nerve-fibre, the primitive and medullary sheaths being only subsidiary structures. The exact function of the sheath of Schwann is not known, but it may play the part of an insulating material, and upon this supposition the structure of a nerve reminds one somewhat of that of a submarine cable. In such a cable each wire is surrounded by gutta percha and other insulating materials, and the bundles are then further surrounded by similar insulating substances to prevent the escape of the electric current, the whole being surrounded by tarred rope, &c. Just in the same way, each axis cylinder of a nerve is surrounded by the white sheath, each fibre is separated from its neighbours by processes from the bundle-sheath, and each bundle is separated from the others by processes of the neurilemma, which latter encases the whole nerve.

The *gray* or *vesicular nerve tissue* consists of a number of small bodies, termed *nerve cells*, which vary much in size, and differ in form, or, we had, perhaps, better say, exist in various stages of development. The simplest are spherical or oval in shape, and, like the other forms, are more or less granular in structure, possessing a somewhat firmer, well-defined central portion, the *nucleus*, which, in its turn, has in the centre a smaller body, the *nucleolus*. The contour of these simple cells is unbroken, and they do not give off any processes. Other forms, however, do give off one or more processes, and when the processes amount to three or more in number, these have a somewhat stellate appearance. Where the cells give off processes, one of the processes, and only one, becomes continuous with the axis cylinder of a nerve-fibre, and this one is termed *the axis cylinder process*. It is not quite certain what becomes of the other processes, but, in all probability, they divide, and their fibrils unite with similar fibrils from other cells. The smallest of the nerve-cells are about the $\frac{1}{3000}$th of an inch; the largest, about the $\frac{1}{300}$th of an inch in diameter. It will be remembered that nerve-fibres only are found in the nerves, but that the nerve-centres, as they are termed, which comprise the brain, spinal cord, and ganglia, are composed of both fibres and nerve cells. In the larger nerve-centres, the nervous elements are supported by a delicate fibrous structure known as the *neuroglia;* this structure contains cells, but these are quite distinct from the nerve-cells to which I have just drawn your attention. I feel I must apologise for having taken up your time in following so closely the details of the structure of the nerve-tissues, but you will, I hope, not regret my having done so. Before we can understand the working of a machine it is necessary that we should make ourselves acquainted with the general features of its construction, and of the relation of its working parts. We will leave the *Anatomy*, that is, the structure, of the nervous mechanism, and turn our attention to its *Physiology*, that is, to its mode of working.

We may, perhaps, get a few rough general notions of the manner which the Nervous System works by comparing it with our wonderful system of Postal Telegraphs. In that system, as every one knows, we have a head office in St Martin's-le-Grand, a number of district offices scattered all over London and the Provinces, and connecting all these offices together we have a number of telegraph wires. Now, with certain restrictions to be mentioned presently, we may take the head office to represent the brain proper, the district offices to represent the subsidiary structures in the brain, the spinal cord, and the various ganglia, while the wires will represent the nerves. Now, we know that, in the Telegraph System, general orders and directions can only issue from the head office, to which office complaints are also addressed, while routine work may be carried on by the district offices, which are also capable of both receiving and despatching messages. Finally, the wires serve solely as the media along which messages pass, such messages being in no way altered or modified as they pass along.

Now, in the Nervous System, we similarly find that all impulses which are the direct result of the will start from the brain proper, or *cerebrum*, and cannot originate in any other parts of the Nervous System. To the cerebrum, also, all impulses pass which produce pain or other sensations. The other nerve-centres can receive and despatch impulses, and much of the routine work of the body, such as Digestion and Secretion, is carried on by them. Finally, the nerves act solely as the conducting wires between the nerve-centres and the various parts of the system to which nerves are distributed. Just as in the telegraph system, so in the Nervous System, the conducting wires have no power of modifying the impressions which they convey, but here the parallel ends. The telegraph wires will carry indiscriminately any message sent along them, whatever may be its nature; it may be a message of hate, it may be a message of love, it may be a pressing invitation to dinner; it may be an equally pressing invitation to pay a debt—along the same wires it will pass. But in the Nervous System it is quite different, for the nerve-fibres have a selective power with regard to the impulses they convey. Some fibres will only convey impressions from the various parts of the body to a nerve-centre, and these fibres are termed *sensory* or *afferent;* the term "sensory" is not a good one, as the impressions these fibres convey do not *necessarily* result in sensation, and it is, therefore, best to term them *afferent*, that is, *in-going* fibres. Other fibres will only convey impressions from a nerve-centre to the muscles, and these are termed *motor* or *efferent*, that is, *out-going*. Another class of fibres convey impressions to the brain which result in sensations of touch, taste, smell, hearing, or sight, and these are termed *special sense* fibres. Still others convey impressions which result in the restraining of certain functions, and these are termed *inhibitory*. Some nerves are made up wholly of one kind of nerve-fibre, and then the same terms are applied to the nerves as to the fibres of which they are composed : when nerves contain fibres of more than one sort they are termed *mixed nerves*.

Another analogy between the Telegraph and Nervous Systems may be noticed here. If one wants to send a message by telegraph, he does not climb up the first telegraph post he comes to and endeavour to despatch it at once along the wires, but he goes to a telegraph office, that is, to one end of the wire, and in like manner it is necessary that the message shall be received at another office, and not at any intermediate part of the wire. In much the same way messages are received in, and despatched from, the nerve-centres only. Hence, if a man has his leg cut off, he still fancies he can wriggle the toes of that foot, and not infrequently he feels a pain in one of his toes. Now, in the first case, the wriggling of the toes, the man is conscious of a certain something taking place in his brain which has hitherto always resulted in the movement of his toes, and although he has now lost the toes, his mind still conceives the same disturbance in the brain as producing the same result. In like manner, when a disturbance reaches the brain from what is left of the nerves of his leg, the mind refers the disturbance, as it has always been accustomed to do, to the former ends of the nerves, that is, to the toes. This shows us that the mind knows nothing of what happens while an impulse is traversing a nerve, but only of that which happens when the impulse leaves or reaches the brain.

In order that we may learn something more of the working of the Nervous System, it is necessary that we should now turn our attention to a class of nervous actions in which the will plays no part, and of which we may even remain quite unconscious; such actions are termed *reflex* or *instinctive actions*, and their nature will be best understood from a few familiar examples. You all remember how, in days longer ago than some of us care to count, it was a common practice for a schoolboy to rub a metal button briskly upon a desk or form and then apply it to the hand or cheek of a neighbour, which resulted in the latter making a more or less vigorous and sudden start. A more elegant form of the experiment, and one sometimes practised, I am told, by persons of mature age, is to apply a hot spoon to a neighbour's hand at the tea-table. In either case, a sudden withdrawal of the part touched results. Now, how is all this brought about? First of all, a message is conveyed to a nerve-centre by an afferent nerve; then in the nerve-centre that impression is, as we say, "reflected," and an impression is sent from the nerve-centre along motor nerves to the muscles, causing them to contract and withdraw the affected part. Now, in all this, the will takes no part. The person whose hand or cheek is burnt does not debate within himself the advisability or not of withdrawing the hand or cheek; it is done instantly, as we commonly say, "without a thought," that is, *instinctively;* and such an action we term a *reflex action.* Numerous other examples of these actions will occur to every one, such as the sudden withdrawal of the hand when it is placed on a very hot surface, the sudden drawing back of the head when a blow is aimed at it, and so on. In order to show the distinction between a reflex action and one that is not reflex, allow me to take another familiar instance. You are about, we will suppose, to cross a busy thoroughfare, and just as you are stepping off the kerb a cab dashes round the corner. You draw back instantly, there is no time for thought, the action is entirely reflex, and, though you are quite aware of what has taken place, your knowledge is *after knowledge.* But, if a nervous old lady wishes to cross a tolerably busy road, she looks first this way, then that, and descrying in the far distance a vehicle coming towards her at a slow pace, she debates within herself the advisability of crossing; perhaps she at length makes a frantic rush, and reaches the further side in safety; probably she draws back, and determines to await the aid of some friendly policeman. Now, in this case, whatever be the result, it is brought about by a distinct effort of the will, and the action is *not* reflex. As an example of a reflex action where there is also an absence of consciousness, I may remind you of the fact that you may lightly tickle the foot of a sleeping person without awaking him, though the foot is withdrawn, and if you question the individual when he awakes you will find that he has no knowledge of having been interfered with. Now, in all reflex actions it is obvious we must have the following structures concerned: a sensory surface to receive the impression, an afferent nerve to convey the impression inwards, a nerve-centre to reflect the impression, an efferent (motor) nerve to convey an impression outwards, and certain muscles by the contraction of which movement may result: these are the essentials of every reflex action.

You will remember that I told you just now that all nerve-centres contain, in addition to fibres, numerous nerve-cells. Now it is highly probable that these cells resemble the points of a railway, inasmuch as they are the shunting-places of the nervous impulses which reach them by afferent nerves. But the analogy is by no means a perfect one, for in shunting on a railway the *same* train passes from one set of rails to the other, and the train is not in any way affected by the process, except in so far as its *direction* is changed. Now when an impulse is reflected in a nerve-centre it is not merely changed in direction, but undergoes profound modification. For instance, when a crumb of bread or particle of salt goes, as we say, "the wrong way," the result is, as you know, a violent fit of coughing. Now in this case the afferent impression must be very slight, yet it gives rise in the nerve-centre to an explosion of energy, which sends impressions along several motor nerves, and produces the powerful contraction of numerous muscles.

Beside the simple reflex actions to which I have referred, and of which I have given examples, there are other very complicated movements constantly taking place, which, though at first due entirely to voluntary nervous impulses, become, after a time, by education, entirely reflex. One or two examples of these will make their nature clear.

We all know how, when the baby first begins to walk, great care and circumspection have to be observed as it slowly progresses from chair to chair, each movement of the little limbs being undoubtedly the result of an impulse coming from the will, and the process absorbing the baby's entire attention. But as the baby gets confidence, and is more used to walking, the actions become less and less the results of voluntary impulses, until, when the little one walks about the house with "the certain step of man," the action of walking becomes entirely reflex, and we know by our own experience that the act of walking requires no effort of the will after the first movements have been initiated. That this is so is apparent from the fact that, as we walk along the streets, our minds are occupied with anything but a consideration of the complicated muscular movements—and they are *very* complicated—by which our locomotion is effected, and if anyone doubts the reflex nature of these movements, let him, as he leaves here to-night, try to walk home, making every step the result of a distinct effort of the will; I am quite sure he will soon give up what will prove an intolerably irksome task.

Another instance of this class of reflex movements is to be found in the art of writing. Doubtless, everyone here remembers, more or less distinctly, the sad trial it was in our early school-days when we were first set to make pothooks and hangers, and we know that every stroke we made was most decidedly the result of a distinct effort of a most unwilling will, and we remember too, how, with some of our companions, it was even found necessary to accompany each stroke with certain muscular movements of the lips and tongue. But now each one of us here possesses, in a greater or less degree, the pen of a ready writer, and when we indite a letter we bestow all our thought upon the matter of our epistle, and none at all upon the formation of the letters; the mere mechanical act of writing has, by education, become reflex.

But now the question arises, Can we in any way find out what happens when an impulse passes along a nerve, or what happens in a nerve-centre when an impulse is received there, and, especially, do we know what consciousness is? I am afraid that the answer to that question, and especially to the last portion of it, is a blank "No;" still there are a few facts which seem to point us in the direction in which a more satisfactory answer may hereafter be obtained. With your kind permission, I will bring the most important of these facts before you.

We have already roughly compared the nervous system to our telegraph system, and we shall in a moment find that the analogy is closer than, at first sight, is apparent. The force which conveys messages along the telegraph wires is what we know as electricity, and there is this resemblance between a telegraph wire and a nerve, that each will convey an electric current; you may use a piece of fresh nerve instead of a wire as a conductor. If, however, you pinch a nerve, so as to destroy the continuity of the substance inside, it will no longer convey a nervous impulse, though it will still convey an electric current; obviously then, though there is a close resemblance between an electric current and a nervous impulse, the two things are not identical.

Another important feature of nerves, which I must very briefly notice in this connection, is what is known as the nerve-current. If a piece of perfectly fresh nerve be taken —that is, a piece from a recently killed animal—and if the two ends be connected by wires with a galvanometer, which, as you probably know, is an instrument for detecting very delicate electric currents, no effect is noticed, no deflection of the galvanometer needle takes place. But if one wire be placed at the middle, and the other at either cut end of the piece of nerve, the deflection of the galvanometer needle indicates a current passing from the middle to the cut end. By varying the experiment it is found that an electric current passes from the middle to *either* cut end, and if one wire be placed near the middle of a piece of nerve, and the other wire farther from the middle, a current will pass from the former to the latter. These currents, be it observed, are perfectly independent of any electrical machine or battery, and are naturally present in the nerve; they are termed *natural nerve currents.*

If while a nerve is, in the manner I have just indicated, connected with a galvanometer, it be stimulated, the galvanometer needle, previously deflected by the natural nerve current, moves backward to the zero point, indicating the passage of a current in the opposite direction to the natural nerve current, and, therefore, antagonistic to it; this phenomenon is known as *negative variation.*

But time, and I fear your patience also, forbid me to carry this intricate but deeply interesting subject further to-night. Some of the facts mentioned seem to point to a close resemblance between an electric current and a nervous impulse, while others prevent us from concluding that the two are identical. As an addition to the latter, I may mention that the velocity at which a nervous impulse travels is vastly less than that of the electric current. The former travels at the rate of about 108 feet in a second, the latter at very nearly 200,000 miles per second.

Fact then forbids us to consider nervous force as the same thing as electricity; but even if it did not we should be but little more advanced in our knowledge, for no one has, as yet, been able to tell us what electricity is, though we have a strong suspicion as to its nature.

But though, in endeavouring to solve the problem as to the nature of nervous force, we must here leave the sure ground of fact for the more treacherous region of hypothesis, there is, I think, no reason why we should not look for a few moments at certain ideas which are floating in the minds of scientists with regard to this matter, and which, if not the truth itself, have every appearance of being the germs from which the truth will eventually spring. Now if we confine ourselves to the impressions which pass by two special avenues to the brain, I refer to the impressions which result in hearing and sight, we come in contact with some suggestive facts. Let us first take the sense of hearing. Now we *know* that sound is produced by the vibrations or tremblings of sonorous bodies. When a bell is struck, or a string plucked, we can see these vibrations, and we know they produce sound, but in order that *hearing* may result, something must be conveyed to the brain: what is that something, and how does it reach the brain? When a sounding body is set in vibration its motion is communicated to the surrounding air, each particle of which similarly vibrates and communicates its motion to the neighbouring particles, thus moulding the air into a series of sound waves, some of which reach the ear. Let us take the case of a sounding string, and, though we know there are countless air particles completely surrounding the string, let us fix our attention, for the sake of simplicity, upon a single chain of such particles extending from the string to the drum-membrane of the ear of a person in the neighbourhood. The string is plucked, and moving first forwards, hits the first air particle in our imaginary chain; that particle, being thus pushed, strikes the second particle, the second the third, and so on all along the chain until the ear is reached. But, after the string has swung forwards, it retreats, and the first particle follows it, the second particle follows the first, the third the second, and so on along the whole line. In this way all our chain of particles is set in rapid vibration, the vibrations corresponding to those of the string. The backward and forward motion just described is well illustrated in the movements of a train of goods trucks during shunting operations. When the engine is backed against a row of trucks the first truck receives a blow, which it passes on to the second, and the shock is in a similar manner propagated along the whole line of trucks. Similarly when, after being coupled up, the engine starts, the first truck receives a pull, then the second, then the third, and so on along the whole line. These operations take place with sufficient slowness to be visible to the eye, and for each shock to be separately audible; the pushing together of the trucks illustrates the driving together of the air particles, the drawing apart of the trucks represents the drawing apart of the air particles. Each air particle in its vibration only swings through a short space, and while it is completing its swing the vibration travels onwards; consequently we shall have, in our chain of particles, a number of portions where the particles are driven close together, these are termed *condensations*, and also a number of portions where the particles are further apart, and which are termed *rarefactions;* one such condensation together with the next rarefaction forms a *wave of sound.* That which is propagated from the sounding body to the ear then is *motion* of the ultimate particles of the air or other medium which extends from the sounding body to the drum membrane of the ear. This consists of a stretched membrane, upon the other side of which is a small hollow cavity, the *drum* of the ear, or *tympanum*, and stretching across this cavity is a small chain of tiny bones, connected on the one hand with the membrane of the drum, and on the other with a similar membrane which fills an oval opening in the back of the tympanum. Upon the other side of this second membrane are the delicate fibres of the auditory nerve, bathed by a watery fluid containing a number of delicate hairs, and also small sand-like particles, and the auditory nerve of course passes up to the brain. When the sound-wave reaches the drum-membrane, that membrane is set in vibration, the little chain of bones passes the vibrations on to the membrane at the back of the drum, which, in its turn, sets in vibration the fluid bathing the auditory fibres. Here let me stay to remind you that so far we are dealing with undoubted facts, facts which have been most abundantly verified, and what do we find? Why, that all along the line *motion* is transmitted, that motion being the result of the motion of the sounding body. Is it so *very* absurd a notion to suppose that during the rest of its journey to the brain, sound still travels in the form of molecular motion, motion, that is, of the ultimate particles, or *molecules* of the nerve? I think not, and I am of opinion that we may figure to our minds quite feasibly a chain of molecules stretching from the nerve ends to their commencement in the brain. Suppose these molecules, in the quiescent state of the nerve, to be in a state of unstable equilibrium, that is, ready to assume a more stable, or, if you like, more comfortable position, the vibrations of the sound-wave reach the end of the chain, and the first molecule falls, in its fall passing on the push to the other molecules; and so a molecular disturbance is propagated along the chain to a certain area in the brain, communicating to that area a similar disturbance, which the mind translates as what we term *hearing*.

If, in the same way, we trace the passage of a beam of light from a luminous body to the eye, we find we are still dealing with molecular motion, only in this case the motion is immensely more rapid, and in the same way we may imagine that a molecular disturbance is propagated by the optic nerve to the brain, producing there a molecular disturbance. If what we have assumed be true, it is no difficult matter to conceive of every nervous impulse as a molecular disturbance travelling to or from the nerve centres along the nerves.

But even if our supposition be correct, we come, you see, at last, for the present at least, to a dead stop. Even if I could tell you, which I cannot, that a certain arrangement of the molecules of a certain area of the brain caused the hearing of a certain sound, or the vision of a certain object, we should still be at a loss, should still be unable to define sensation, much less thought itself, for the question would still arise, *Why* should such a molecular arrangement result in hearing or vision? You see between the molecular arrangement and the sensation comes that mysterious something, which we term *consciousness*, of which we know absolutely nothing. There are, I am aware, some people who talk of the brain *secreting* thought and sensation, just as we speak of the liver secreting bile, or the salivary glands secreting saliva, and these *materialists*, as they are called, tell us these molecular disturbances *are* sensation. But I beg to differ from this view, and venture still to ask, " How does consciousness come in?"

But my time has altogether gone, and I must leave you to pursue at your leisure this deeply interesting subject, interesting if we look upon the nervous system merely as the controlling agency of the various animal functions, far more interesting still when we regard it as the depository in man of those higher powers which raise him above the level of the brute, and by virtue of which he reigns in the great world of mind, unrivalled and supreme.

II.

THE STARLIT SKY.

OF all the grand and beautiful sights which this universe affords to man, none exceeds in grandeur or in beauty the magnificent one which meets his view when he fixes his gaze upon the starlit sky—a sight which in all ages of the world has provoked in men's minds the deepest feelings of reverence, curiosity, and awe.

In the early days of the world's history, untutored man, feeling the necessity of acknowledging some power without, greater and mightier than the conscious self within him, thought that he saw in the heavenly orbs the embodiment of that power, and bent to them accordingly in reverent and adoring worship. Later on, when the motions of the heavenly bodies were but little better understood, men, who were perhaps not all impostors, fancied they saw in those seemingly erratic movements something analogous to the ever-shifting, ever-changing aspect of human affairs, and sought to prove that the one was but the outcome of the other; while in all times the poet has drawn from the sky his most beautiful and grandest similes. It is not however from the standpoint either of the devotee, the astrologer, or the poet, that I wish you to gaze upon the stars to-night, but rather as intelligent observers, who, viewing, not for the first time, with wonder and delight those scintillating gems, are desirous of knowing something as to their number, their distance and size, and above all, if possible, the nature of the materials of which they are composed.

The number of the stars is popularly supposed to be infinite, but this is to a large extent an optical illusion, the total number of the stars capable of being seen by the naked eye not exceeding some 5,000, and of these only one half, or about 2,500, will be above the horizon at one and the same time. When, however, we call to our aid that wonderful instrument the telescope, the number does, in sober truth, seem to approach infinity, every improvement in the power of the telescope being immediately followed by the discovery of fresh and more distant stars.

When we attempt to ascertain the distance of the stars, we find that we have to deal with numbers which are truly enormous, and are almost beyond conception. Let us first take as an example the sun, which is really our nearest fixed star. As we are all aware, its distance from the earth is about ninety-two millions of miles, a distance the numerical statement of which is very familiar, but, which, perhaps because so familiar, fails to convey an adequate idea of the distance which it implies. A familiar illustration may perhaps help us better. An express train travels at the rate of about fifty miles an hour, and if it were possible for you and I to start by such a train to-night, on a journey to the sun, it would take us more than two hundred and ten years of continuous travelling to reach our destination. Passing into the more distant regions of space, until we reach those stars which are commonly known as "fixed" stars, we find that their distances from us are so enormous that any attempt at expressing them in ordinary miles is useless, as it simply results in long strings of figures which fail to convey any idea of the distances they represent. Consequently, a much larger unit has to be employed, and a useful one is found in the velocity with which light travels through space, which, as you probably know, is about 184,000 miles, or nearly eight times round the earth in a second. Spite of this enormous velocity it takes more than three and a half years for light to travel to us from the nearest fixed star, (*a* Centauri), while from the more distant of the heavenly bodies light takes many centuries to reach the earth. It has been calculated that if a boundless ocean stretched from us to remote space, and if upon that ocean a fleet of merchantmen was despatched to the nearest fixed star, with instructions to the Admiral to drop a pea at the end of each mile of the journey, ten thousand vessels, each of twelve hundred tons burthen, would be required to carry the peas. If the distances of the stars are so enormous, what then must be their size? Again, let us refer to the sun. The sun is a globe equal in bulk to one and a quarter million such globes as ours, but the matter of which it is composed being lighter, bulk for bulk, than the materials forming the earth, it is only about three hundred thousand times as heavy. This difference in the specific gravity of the sun, together with its larger size, will so affect the attraction of its centre for objects upon its surface, that a body weighing one pound upon the earth would weigh rather more than twenty-seven pounds at the surface of the sun, and if my able assistant were to be transported to our great luminary (which may the gods forbid), he would, instead of weighing as he does at present, some twelve stones, weigh about two tons, and any opinion which he might subsequently express respecting the constitution of the sun, would be entitled to considerable weight. To give you an adequate idea of the immense size of the solar system, allow me to make use of another familiar illustration. As you know, the moon revolves round the earth at a distance of, roughly speaking, 230,000 miles. Now, if it were possible to transfer the earth and the moon to the sun, still keeping them at the same distance apart as they are now, and if it were further possible to place the earth exactly in the centre of the sun, there would be room for the moon to revolve round the earth, at the same distance as it does now, *in the sun*, and beyond the orbit of the moon there would be more than two hundred thousand miles of sun to spare. But if the sun were removed to the distance of the nearest fixed star it would shine only as small a point of light barely visible to the naked eye, so that there can be little doubt that many of the stars are much larger than the sun.

Having just now told you something about the great distance of the stars, it may seem presumption in me to pretend to tell you about the nature and condition of the materials of which they are composed; but that this is nevertheless perfectly possible it will be my endeavour to show you this evening. Of course we do not pretend to know *all*, or anything like all, about the stars, but we are possessed of a considerable amount of important and interesting information concerning them.

In order that I may make clear to you the manner in which this information has been obtained, it is necessary that I should take you into one of the most beautiful branches of physical science, viz.: that of Optics or Light.

Light, according to the modern theory, which is almost universally accepted, is the result of motion. Every luminous body in the universe is in a state of *unrest*, its every particle vibrating with enormous rapidity, and just because this is so it gives out light. In order that these vibrations may affect our brains, it is necessary that some medium should exist by which they may be conveyed to the nerves of sight, which will convey them to the brain. Therefore we believe, or perhaps I had better say, we suppose, that there exists an extremely rare and highly gaseous medium, which is termed the *luminiferous ether.* This, we presume, extends to the farthest bounds of space, surrounds every opaque object upon the earth, and penetrates the interstices of transparent bodies, including, of course, the humours of the eye. The vibrations of luminous bodies are taken up by the ether, and by it conveyed to a delicate screen, the *retina*, at the back of each of our eyes, and which is an expansion of the optic nerve, or nerve of sight, by which an impression is conveyed to the brain. To make this process thoroughly clear, allow me for a moment to draw your attention to the analogous phenomena of sound and hearing. A stretched string is plucked, and swings backwards and forwards; in so doing it sets in motion the air particles in its immediate vicinity, causing each one of them to swing backwards and forwards also. Each air particle passes on the motion which it has received, and eventually the particles contiguous to the drum membrane of the ear are set in motion; this causes the drum membrane itself to vibrate, and the motion is by it passed on through several complicated structures, until at length it reaches the ultimate fibres of the auditory nerves. Now in this case, you see, we are throughout dealing with *motion*, each one of the bodies concerned not merely vibrating as a whole, but each one of its molecules or ultimate particles also vibrating; and just in the same way that the vibrations of sonorous bodies result in sound, do the vibrations of luminous bodies produce light. The manner in which the air conveys sonorous vibrations to the ear, is also similar to that in which the ether conveys luminous vibrations to the eye. There are, however, two important distinctions to be noted between sonorous and luminous vibrations. First, the direction of vibration in a sound wave is *longitudinal*, that is to say *in* the direction in which the wave is travelling; the vibrations of the ether particles in a wave of light are *transverse*, that is, *across* the direction in which the wave is moving. Light-waves, therefore, resemble water-waves. The second important difference between vibrations producing sound and those producing light is in their rapidity. Sonorous vibrations are comparatively slow, those of light extremely rapid. Suppose the string of a piano is struck, and let it be the string producing the middle C, it will perform exactly 256 complete vibrations in a second. Now suppose further that we have the power of indefinitely increasing the rate at which the string vibrates; as that rate increases, the pitch of the sound produced rises higher and higher, until a rate of 38,000 vibrations per second is reached, when the sound ceases to be audible, the rapidity of the vibrations having reached the limit of human hearing. Let the rate of vibration be still further increased until the string performs four hundred and seventy-four and a half millions of millions of vibrations per second. Vibrating at this enormous rate, the string produces no sound audible to human ears; but its vibrations, which are far too rapid to affect the auditory nerves, do affect the more delicate nerves of sight, and the sensation of *red light* is produced, while if the rate of vibration be increased to six hundred and ninety-nine millions of millions in a second, the light produced will be *violet.* At this enormous rate do the molecules of luminous bodies, and the particles of luminiferous ether vibrate; and we perceive now that there is not merely poetic beauty, but also sober truth in Shakespeare's lines when he bids us

"See how the floor of Heaven
Is thick inlaid with patines of bright gold :"

and tells us that—

"There's not the smallest orb which thou beholdest
But in its motion like an angel sings,
Still quiring to the young-eyed cherubins :
Such harmony is in immortal souls;
But whilst this muddy vesture of decay
Doth grossly close it in, we cannot hear it."

An important discovery with regard to the nature of ordinary white light was made by the great Newton. Into a darkened room a beam of sunlight was admitted through a hole in the shutter, and in the path of the beam was placed a prism of glass, having a triangular section, in fact, not unlike one of the plain glass drops from the lustres which ornament our mantelpieces. The result of the interposition of this prism in the path of the beam of light was to produce upon the opposite wall an elongated band of colours, similar to those of the rainbow, in place of the round white image of the hole in the shutter, which would otherwise have been formed. Any one may perform the experiment, and upon comparing the path of the beam when the light is not intercepted by the prism with its path when the prism is used, it will be found that in the latter case the beam of light is *bent out of its straight path*, or, as we say, *suffers refraction;* moreover, it will be seen that some of the rays are more refracted than others. The rays of which a beam of white light is composed are all acted upon by the prism in this manner, but they are *unequally* affected by it, they are not all equally *refrangible*, the red lights are least refrangible, the violet rays most so, the other colours occupying positions between these two extremes. Were the rays equally refrangible, although the beam of light would be bent out of its path *as a whole*, the separate rays would all fall upon the same spot, and a white round image of the hole of the shutter would be formed, just as if no prism were employed, except that the *position* of the image would be different. Owing, however, to the unequal refrangibility of the rays, when they pass through the prism they are spread out, and each falls upon a separate spot on the screen, thus forming an elongated, coloured band, in place of a round, white image.

By this experiment Newton effected the *analysis*, or decomposition of white light, and was led to the conclusion, subsequently proved to be correct, that white light is made up of a number of coloured constituents; these tints are really infinite in number, but it is usual to recognise seven primary colours,—red, orange, yellow, green, blue, indigo, and violet. Not satisfied with having effected the *analysis* of white light, Newton set to work to perform its *synthesis*, to put together, that is, the rays which, by his prism, he had succeeded in separating. This he succeeded in doing by employing two prisms instead of one, the second being reversed in direction with regard to the first, thus, the first being base downwards, the base of the second was placed upwards, consequently the second prism exactly reversed the work done by the first, and by it the dispersed rays were brought together again, and a white image formed just as if no prism at all were employed. This experiment proves *synthetically* what the first one showed *analytically*, viz.: that white light is composed of various coloured constituents. Newton's successful investigation into the nature of white light was the first in a long series of brilliant discoveries which have resulted in a large amount of knowledge respecting the nature of the heavenly bodies, and as we shall have to refer to these more than once this evening, you will perhaps allow me to remind you of one or two terms we shall have to employ. When any light is made to pass through a prism, the appearance we get upon a screen is termed a *spectrum;* if sunlight be employed the spectrum is, of course, the *solar spectrum.* When the band of colours is unbroken from end to end, as in the case of Newton's experiment, the spectrum is said to be a *continuous* one. When the source of light is a white hot, or as we say, *incandescent* solid, liquid, or densely gaseous body, the spectrum obtained by examining the light with a prism is always a continuous one.

Turning our attention from ordinary white light to light containing rays of one colour only, let us see the result of examining such *monochromatic* light by means of the prism. Newton, in his experiment, as we have seen, admitted light into a darkened room through a hole in a shutter, but the apparatus now employed is somewhat different, and a little more complicated. The source of light employed is usually the electric light, or the lime-light, either of which gives white light resembling that of the sun. The light is enclosed in an ordinary magic lantern, and passes through a narrow slit, which is much more convenient than a round hole. The prisms are usually hollow prismatic bottles, containing a highly refractive liquid (bisulphide of carbon), and after passing through the prism the light is focussed by a lens upon a screen. This is the method employed for lecture purposes; in the laboratory a much more compact instrument, termed a spectroscope, is used.

A monochromatic light, which is easily obtained, is a sodium flame. A piece of rag or cotton waste is soaked with a solution of salt in methylated spirit; upon lighting this it is noticed that all colours disappear, and every face is covered with a sickly, ashen-grey hue, which is anything but agreeable to contemplate. The reason of this curious phenomenon is this: colours are not inherent properties of certain bodies, but depend upon the power which such bodies have of absorbing some of the rays of white light, and reflecting others. A body which is blue absorbs all but the blue rays, which it reflects; a red substance reflects red rays and absorbs the rest; a substance which *absorbs* all the rays of light which fall upon it is black, while a body which *reflects* all the rays of light falling upon it is white. Hence, when the source of light only emits yellow rays, only yellow substances will appear of their natural colour. Other substances absorb yellow rays, and consequently appear black in a yellow light.

What kind of spectrum shall we get if we use a sodium flame as our source of light? Let us see. Remember, the light we are now going to use is that proceeding from incandescent sodium vapour, and you see upon the screen, in place of the brilliant band of colours produced from white light, a single bright yellow band, occupying the same position as the yellow of the continuous spectrum. Now, this spectrum we term a *bright line*, or *radiation spectrum*, and whenever the source of light is an incandescent gas, we always get a bright line spectrum; usually there is more than one band, and sometimes several, but the spectrum is always one of bright lines, with intervening dark spaces. The points of special importance to be noted concerning these bright line spectra, are these :—every element, when its vapour is thus made incandescent, always gives the same band or set of bands; the bands of any particular element are different from those given by any other element. If several elements be present in the same flame, each element will give its own particular bands, just as if it alone were present. As examples of these radiation spectra, I may tell you that the vapour of copper gives a series of green bands, zinc vapour bands of blue and red. In each case you see these vapours emit only certain parts of white light; the light which they give results from vibrations at one or more rates only, and is capable of producing waves of only one or two different lengths.

You will at once perceive that these radiation spectra are of great importance, for, if in examining a particular light, we find the spectrum to be one of bright lines, we know not only that the source of light is an incandescent gas, but we know what that gas is. We must now notice a third kind of spectrum, which also yields us very important results. We will vary our experiment with sodium vapour. Instead of making the vapour incandescent, and using it as a source of light, we will cause a beam of white light to pass through a cloud of sodium vapour, which we will obtain by melting sodium in front of the lantern, and meanwhile I will get you to carefully watch the screen. There, you see what we get! A continuous spectrum, due to the white light, but a strong black band runs vertically across it, just where the yellow and the orange blend, in the same position, that is, as that occupied by the bright band of incandescent sodium vapour. In the same manner, if we caused white light to pass through the vapour of other elements, we should get a bright spectrum crossed by dark lines, the positions of which would always correspond with those of the bright lines obtained when the same gases are rendered incandescent, and used as sources of light. These spectra are called *absorption spectra*, because a part of the light is stopped, or *absorbed*, in passing through the vapour, and we see that every element is capable of stopping the same rays as it itself emits, *and no others*.

We are now in a position to appreciate the value of these discoveries, which are the result of much patient toil upon the part of many investigators. It is easy to see that if we can but get light from any source, whether it be a gas flame a few feet away, or a star many millions of miles distant, we have in the spectroscope an instrument which enables us to tell the nature of the source of light, and the elements present in it; this method of analysing bodies by means of the light which they emit is termed *spectrum analysis*. The delicacy of this method will be evident, when I remind you that the three-millionth part of a milligramme of salt in a flame is sufficient to reveal the presence of sodium (one of its constituents), by giving its characteristic band.

In applying this method of spectrum analysis to the heavenly bodies it is only necessary to remember that a continuous spectrum always indicates an incandescent solid, liquid, or densely gaseous body as the source of light, but tells us nothing as to the nature of the materials of which it is composed; that a bright-line spectrum tells us that the source of light is an incandescent gaseous mass, and the particular lines exhibited show us also *what* gases are present; and finally, that a spectrum crossed by dark lines indicates a central incandescent nucleus surrounded by a gaseous atmosphere the constituents of which are at a very high temperature, but are not so hot as the nucleus.

THE NEBULÆ.

One of the most interesting series of bodies in the universe comprises those hazy, irregular, indistinct patches of light, known as *nebulæ.* But few are visible to the naked eye; but the telescope brings into view a very large number of them, some being so remote, that it is calculated that light takes sixty thousand years to travel from them to us. Before the discovery of spectrum analysis much controversy took place as to the nature of these bodies, some thinking them to be mere clouds of star-dust, others considering that they consisted of groups of stars so remote that they were not individually distinguishable. The spectroscope when applied to the examination of the nebulæ soon showed that they are divisible into two groups, those which are groups of stars, and those which are masses of gas. Moreover, the spectrum obtained from some of the nebulæ consists of three bright lines, two of which have been recognised as identical with two of the lines of hydrogen gas, while the other may be indicative of nitrogen. These nebulæ evidently consist of glowing masses of gas, and there is a theory concerning them, due to Messrs Thompson and Tait, which we must very briefly notice. These eminent scientists believe that the nebulæ are immense groups of stones in rapid motion amongst themselves, and constantly "colliding" with, and jostling against each other, the heat thus produced being sufficient to render incandescent any surrounding gas.

COMETS.

The next bodies to engage our attention are those erratic phenomena, comets. The spectrum obtained from the head of a comet is a radiation spectrum, but the lines are not so sharply defined as in the nebular spectra; they are broader and more irregular, and are known as "channelled spaces." Now a channelled-space spectrum, as compared with a bright-line spectrum, indicates a reduction of temperature, and in the head of a comet we seem to be dealing with hydro-carbon gases, the temperature of which is somewhat lower than that of the nebulæ. The tail of a comet gives a continuous spectrum similar to that of the sun, showing that it is not self-luminous, but shines by the reflected light of the sun. Again Messrs Thompson and Tait come in with a theory. They tell us that the head of a comet is just a bit of a nebula in motion as a whole, though its component particles are still banging about and "colliding" with each other; the tail, these scientists assume, is formed by a cloud of dust from the colliding masses, which the head trails behind it, and which is illuminated by sunlight.

Falling-Stars and Meteorites.

We are all well acquainted with the phenomena of "falling-stars," which are frequently visible on a clear night, and we have all probably seen specimens of meteoric stones in our museums. Now in both these kinds of phenomena we are dealing with the same substances, both have the same celestial origin. In falling through our atmosphere, friction against it produces sufficient heat to render the falling mass incandescent, and so burn it; in the case of a falling-star, all the mass is burnt up before it reaches the earth, but in some cases a residue is left unconsumed which falls upon the earth as a meteoric stone, sometimes improperly termed a "thunderbolt." There is, of course, no difficulty in analysing meteoric stones by the ordinary methods of analysis, and they have been classified according to their most prominent constituents; amongst other substances, iron, nickel, and sulphur are abundantly found. The light of falling-stars has also been examined by the spectroscope, and the results of these examinations show that their light is due to incandescent sodium, magnesium, and other substances which become incandescent at a comparatively low temperature.

As you are aware, scarcely a starlight night passes without one or two falling-stars being visible, but at some periods of the year perfect showers of these objects are visible, the month of November being, in this respect, very prolific. Moreover in some years the star-showers, even in November, are much more brilliant than usual. In fact, it is found that these brilliant displays of celestial fireworks occur at regular periods ; and Schiaparelli, an Italian astronomer, has discovered that some of these periods exactly correspond with the periods of certain comets. From this it would seem that when we witness one of those grand star-showers, and

"All Heaven bursts its starry floors
And strews her lights below,"

we are in reality passing through the tail of a comet.

An interesting experiment devised by Mr Norman Lockyer is worthy of notice here. He took some meteoric stones and placed them in a tube from which the air was exhausted. The gases given off from the meteorites in this vacuum were rendered incandescent, first by passing through them an electric spark of low temperature, and then by passing an electric spark of high temperature, the spectrum in each case being obtained ; in the first case the spectrum precisely corresponded with that of the head of a comet, and in the second with that of a nebula.

Here then we have a connection indicated on the one hand between nebulæ and comets, and on the other between comets and meteors, and we are led to the conclusion that all these are merely different forms of the same phenomenon. I have, however, no desire to force upon you this or any other conclusion ; of facts, and of facts only, do I wish to speak authoritatively. In this matter therefore I have only to say to you, There are the facts, here is the theory; as to the facts there can be no manner of doubt, as to the theory, judge ye for yourselves.

THE STARS.

When we turn to the fixed stars we find that we have to do with bodies of a different nature from nebulæ and comets, bodies which give us quite another kind of spectrum. We have hitherto been speaking of bodies which give us radiation spectra; all the stars which have been examined yield absorption spectra—spectra, that is, exhibiting a coloured band crossed by dark vertical lines. Spectra of this kind, as we know, indicate a dense central nucleus surrounded by an atmosphere of heated gases. According to the character of their spectra, stars are divided into three or four groups or classes. The complexity of the stellar atmosphere varies: in some stàr-spectra the dark lines are comparatively few, in others they are very numerous. In some star-spectra the absorption lines are very fine, in others they are more strongly marked; white stars yield spectra of the first kind, red and yellow stars yield spectra of the second kind. Indeed the special colour of a star seems to depend upon the amount of absorption which takes place in its atmosphere. Those constituents of white light which are absorbed by the star's atmosphere are of course wanting, and the residual constituents give the peculiar tint to the star.

The elements present in the stellar atmospheres may be easily determined by comparing the positions of the dark lines with the positions of the bright lines obtained by examining the light of various incandescent terrestrial substances. In this way the elements hydrogen, sodium, magnesium, calcium, iron, bismuth, tellurium, antimony, and mercury have been detected in the atmosphere of the star Aldebaran; and sodium, magnesium, calcium, iron, and bismuth are also known to be present in the star Alpha, in the constellation of Orion.

In the stars then we are dealing with bodies which are much more condensed than nebulæ and comets. A good example of this class of celestial bodies is found in the sun; and as much more is known of that body than of any other star, we will, if your patience is not exhausted, consider its constitution a little in detail.

THE SUN.

Several years ago, Dr Wollaston, in examining the spectrum of the sun, noticed that it is crossed by an enormous number of dark vertical lines. These lines were subsequently studied and mapped out with great accuracy by Fraunhofer, and they therefore are termed *Fraunhofer's lines.* For a long time these lines were a mystery to philosophers, but at last the riddle was solved by Kirchhoff, who showed that they must be caused by the absorption of some of the constituents of white light by some atmosphere outside the sun. That this explanation is correct is proved by the experiment of passing white light through sodium vapour, which latter, as you know, stops the yellow rays which it would emit if it were incandescent.

From the researches of Kirchhoff and others it seems evident that the sun consists of a central nucleus which emits white light, and is known as the *photosphere*, or light sphere, and is that part of the sun which we see every day when it is not obscured with clouds, and that outside this is an atmosphere containing highly heated vapours of such bodies as sodium, magnesium, iron, zinc, calcium, nitrogen, chromium, and others.

But this is by no means the whole of the matter. What we see of the sun under ordinary circumstances is by no means the whole of it; when a total eclipse of the sun takes place, parts of the sun which are ordinarily invisible, because less bright than the photosphere, are rendered visible. A total solar eclipse, as everybody knows, results from the opaque body of the moon coming between the earth and the sun, and obscuring the photosphere. As soon as this takes place the following appearances are seen. First, surrounding the now obscured photosphere is seen a brilliant red envelope containing curiously-shaped bodies many thousands of miles high; this envelope is known as the *chromosphere*, or colour sphere. The red prominences are shown by the spectroscope to be glowing masses of hydrogen gas, which are in constant motion, sometimes rushing out from the sun many thousand miles into space, sometimes as rapidly retreating towards the photosphere. These rapid movements show us that this part of the sun is subject to storms beside which the fiercest tornadoes which occur upon our globe are the merest summer zephyrs. The chromosphere itself is found to consist of incandescent hydrogen mingled with vapours of sodium and magnesium. Between the chromosphere and the photosphere is a thin layer, the *reversing layer*, which contains the gases which produce Fraunhofer's lines; when the photosphere is obscured these dark lines become bright.

Outside the chromosphere is an envelope of very light, faintly luminous gas, shining partly by reflection, partly by its own light, which is known as the *corona*. This usually extends in the form of rays some thousands of miles into space, and in the last total solar eclipse in 1878, there were three of these rays, arranged somewhat in the form of a weather-vane, and shining like burnished silver. In former eclipses the corona extended about half a million of miles on each side of the photosphere, but in the last eclipse it was considerably smaller, and there were other evidences of a general shrinking of the solar envelopes. Such is the character then of a typical star, the one with which we are best acquainted, and, by way of summary, we may say that it consists of a central nucleus, the photosphere, that immediately outside of this is an atmosphere of highly heated gases, that outside this again is the chromosphere with its hydrogen flames, and finally outside the whole is the corona or halo.

THE NEBULAR HYPOTHESIS.

And now in conclusion let us consider for a moment if we cannot find some conclusion to which the facts we have just been considering seem to point. Are the celestial objects we have been studying all perfectly distinct and independent phenomena, or are they merely phases in the development of the same class of objects? Long before the discovery of spectrum analysis, Immanuel Kant, a German, and Laplace, a Frenchman, enunciated a theory concerning the origin of the solar system, which assumed the latter to be the case. According to this, so-called *nebular* hypothesis, the whole of the solar system was at one time a mass of gas such as we believe the nebulæ to be at the present time. Rapid rotation being set up in this gaseous mass, it assumed the form of a thin disc, and at length, centrifugal force overcoming cohesion, whole rings or fragments flew off from the edge of this disc, and contracted into spheroidal masses, such as we know the planets to be. But in these masses the velocity of the outer edge would be greater than that of the inner, and this would tend to cause the spheroid to rotate upon its axis. This process being several times repeated, and the central mass shrinking as it cooled, we eventually obtain a central body with several spheroidal bodies revolving round it in orbits which are smaller the nearer they are to it. Now as you have seen, spectrum analysis certainly seems to support this hypothesis, so far as its revelations of the nature of nebulæ, comets, stars, and the sun are concerned, but it can tell us nothing about the planets, as they shine only by the reflected light of the sun. We, however, know that the *in-*

terior planets, Mercury, Venus, Earth, and Mars, are on the average about five times as heavy as water, while the *exterior* planets, which are much larger, are also much less dense, Jupiter, Saturn, Uranus, and Neptune being on the average scarcely so heavy as water; and we also know that one at least of the satellites of these bodies is little else than a mass of gas. However it is not my business to force upon you any theory or hypothesis. The facts which I have brought before your notice are open to but little doubt, and asking only for a fair, conscientious, and unprejudiced consideration of those facts, I must leave you to accept or reject any hypothesis founded upon them, as your judgment may dictate.

But now I must bring you back to Mother Earth, from which I fear I have detained you too long. In bringing these interesting facts before you, my object has been, not to satisfy you with knowledge; but rather to give you a desire for more. I shall have succeeded in my object if I have taught you to look with somewhat widened interest upon the starlit sky, if I have shown you that bound up with the history of each one of its shining orbs are facts of deepest interest to us all, and if I have convinced you that hazy nebula, and flaming comet, glittering star, and gorgeous sun, as they look down upon us from their azure thrones, so stately and so still, eloquent in their everlasting silence, changeless in their everlasting change, have each some wondrous tale to tell, some secret to unfold.

III.

PRE-HISTORIC MAN.

TO the thoughtful and enquiring mind there are two subjects of frequent contemplation and of absorbing interest—the Future and the Past. Standing, as it were, upon a narrow islet between two boundless oceans, man is ever striving to pierce the veil which hangs on either hand.

Happily for him, the veil of the future is impenetrable, and he can learn but little of that which is to pass in the time to come; but with the past it is far otherwise. From the pages of written History, from the memorials which men of the former time have left behind them, and even from judicious groping in the dim twilight of tradition, man may learn much as to the manners and customs of those who have gone before him; and where history and tradition fail, geology takes up the story and carries him back to eras indefinitely remote, bringing him face to face with generations of living creatures who peopled this earth long ere history or tradition dawned. It is with such an era, though by no means a remote one, that we have this evening to deal.

As you are aware, until some half-a-century since it was the general belief that this world of ours was very young, and the contrary opinion, held only by the very few, was indignantly scouted by a generation which, misled by certain figures upon the tops of their Bibles (for which, by-the-bye, there is not the slightest justification in the text), clung obstinately to the belief that the existence of the world was comprised within some six thousand years. As time went on the new opinion gained ground, but even when it was generally conceded that, whatever else in geology might be true or false, the world was a very old world, it still was supposed, and the belief was shared in even by scientific men, that the entrance of man upon the scene could not possibly date farther back than the period I have named.

About fifty years ago, however, certain discoveries were made which, though at the time imperfectly understood or altogether ignored, have gradually resulted in a change of opinion in this respect also, until, at the present time, few persons seriously doubt that the antiquity of man is greater than that assigned to him by the old theologians. It is to the nature of these discoveries, and the conclusions to which they seem to point, that I desire your kind attention this evening.

The discoveries to which I refer are, as you probably know, those of implements of undoubtedly human manufacture in juxtaposition with the bones of animals which are either extinct as regards the locality in which their remains are found, or have altogether vanished from the face of the earth. These implements are usually such as are among the necessaries of savage life: hatchets, axes, spear heads, arrow heads, knives, scrapers, spindle whorls, and so on. It would, of course, be utterly absurd in me to attempt to give you in the compass of a single lecture anything like a complete account of these discoveries, and I therefore propose to give you a very brief *résumé* of the general results of modern research in this direction, and then to treat somewhat more in detail a particular case in which these discoveries have been made, in order to show you the bearings which they have upon the question of man's antiquity.

The sources from which pre-historic implements have been obtained are various; but amongst others I may mention the peat bogs and kitchen middens of Denmark, the lake dwellings of Switzerland, Ireland, and Scotland, the burial mounds (tumuli and barrows), of our own and neighbouring countries, and the limestone caves of Great Britain and the continents of Europe and America. Collating all the remains of pre-historic man which have been derived from these various sources, it is found that they represent three distinct epochs, each characterised by some one material most frequently used for the manufacture of the implements found. In the oldest period stone was the material employed for the implements manufactured, and this epoch in human history is known as the *Stone Age.*

This epoch undoubtedly covered a long period of time, and it is found convenient to subdivide it into two periods, in accordance with the amount of skill shown in the formation of these stone implements. In the first of these periods, known as the *palæolithic*, or old stone age, the implements are very rough, and shew no trace of artistic skill or attempt at ornament. In the latter period, known as the *neolithic*, or new stone age, much more skill was shown in the formation of weapons and tools, and the majority of those which have been found are carefully polished, and in some instances rude attempts at ornamentation have been made. In the stone age bone implements were also used, such lighter tools as pins, needles, fish-hooks, and such weapons as harpoons being made from this material; in fact, wherever stone implements are found those of bone are also discovered.

Succeeding the Stone Age comes an epoch in which bronze was the prevalent material in use for the manufacture of weapons and tools; this epoch has accordingly been named the *Bronze Age.*

Coming nearer to historic times we find that iron has taken the place of bronze, and this epoch is accordingly known as the *Iron Age;* it of course overlaps the period of history and reaches to our own day.

The peat bogs of Denmark have yielded a rich harvest of pre-historic remains, and a peculiar feature of these deposits is the character of the vegetable remains found in them. At the present day, as every one knows, the prevailing forest tree of Denmark is the beech, and in the surface deposits, remains of this tree are found. Lower down, however, the beech gives place to a variety of oak having the fruits attached to the branches by a stalk or peduncle, and therefore termed the *pedunculated* oak. Lower still we come upon another variety of oak, termed the *sessile* oak, because it has scarcely any foot-stalk to the fruits, these being attached directly to the branches. Going still lower, that is still further back in time, we come to the oldest deposits in which any traces of man have, in these bogs, been found; and here we find that the vegetable remains include neither oaks nor beech, but are those of the Scotch fir, which was undoubtedly at this period the prevailing forest tree of Denmark. In conjunction with all these vegetable remains, human implements are found, and the three great epochs are well represented. The iron age seems only to extend as far back as the beech; bronze implements are found in conjunction with the pedunculated oak, and extend back to about the middle of the epoch when Denmark was occupied by the sessile variety. Finally, stone implements are found beneath this, down to the lowest strata which contain remains of the fir tree; the stone tools, however, are all neolithic, none of them belonging to the older stone period. Next we come to the kitchen middens, as they are termed, of Denmark. These, as their name implies, are huge heaps of rubbish, the refuse of the meals of the savages who left them. They are sometimes a thousand feet in length, and vary in height from three to ten feet. They consist almost entirely of shells, burnt bones, and other food refuse, and, in conjunction with these, knives, spears, and other implements. The shells found in greatest abundance are those of the oyster, mussel, and periwinkle, showing us that the taste of pre-historic man in regard to shell fish was much the same as that of his modern descendants. Some of these kitchen middens belong entirely to the stone age, some to the bronze, some to that of iron, while others yield remains belonging to all three periods, but in no instance are the stone implements palæolithic.

A most interesting series of pre-historic remains are the lake villages which are found most abundantly in the Swiss lakes. It appears to have been the custom of the ancient inhabitants of Switzerland, Ireland, and Scotland, to build villages upon piles driven into the shallow parts of the lakes. The object of these pile dwellings was probably to protect the inhabitants from the incursions of wild beasts, and probably also to prevent the too frequent visits, friendly or otherwise, of neighbouring tribes. Altogether nearly two hundred of these villages have been discovered, and they are not found in a greater depth of water than about fifteen feet. From these villages many pre-historic remains have been recovered, and, like the kitchen middens, some villages seem to have belonged to the three successive ages of stone, bronze, and iron, while others belong exclusively to one or other of these periods. Here again the stone implements belong entirely to the later or neolithic period.

A series of human remains which is now considered as undoubtedly pre-historic comprises the tumuli, or barrows, of which so many have been found in our own island. These mounds are, as you know, the burial places of the former inhabitants of Britain, and some of them undoubtedly date as far back as the neolithic period. Some of the barrows are long, and others round, and it is a curious coincidence that the shape of the skulls found in them corresponds with the shape of the barrow in which they are discovered, long barrows yielding long skulls, round barrows round skulls. From these barrows we also gather that in the neolithic age the dead were buried in a sitting posture, that cremation was in vogue during the bronze age, and that the men of the iron age buried their dead, much as we do at the present day, in an extended position. From these barrows we also learn that it was the custom to hold a feast at a funeral, and I am afraid that at these feasts the bill of fare was not always limited to perfectly legitimate viands, cannibalism being apparently an "amiable weakness" of our early ancestors. A series of objects which has always attracted the antiquarian is that which comprises the numerous menhirs, or standing stones, and the cromlechs, or stone circles. With these the world has been long familiar, and it has been customary to consider them as the remains of temples and monuments left to us by the Druids. Their age has however doubtless been underrated, and though some may belong to historic times, most have a much greater antiquity and are coeval with the bronze implements at least. We have in Homer a remarkable proof that such monuments were, even in his day, in existence, and were so old that their very purpose was forgotten. You will remember his account of the games at the funeral of Patroclus, and you may probably remember that Nestor points out the goal for the chariot race in words which have been thus translated:—

> "Plain is the goal
> Which now I show to thee, nor canst thou miss it.
> Where narrowest is the way, and all the course is smooth,
> Rise two white stones, set there to mark the grave
> Of some one long since dead, or form
> A goal for men in ages past."

Perhaps the most important sources from which prehistoric remains have been obtained are certain limestone caverns, of which there are numerous examples in our own and neighbouring countries. These caverns, which are only found in limestone rocks, contain the bones of animals belonging to species now extinct, or removed from the locality in which their remains are found, and in many instances, stone implements are found in juxtaposition with these remains, disposed in such a manner as to leave no doubt that the bones and the stone implements were deposited about the same time. These caverns have been formed by the action of water upon the limestone, and the interiors are beautifully decorated with columns of crystalline limestone, while pendants of the same material hang from the roof, and bosses rise up to meet them from the floor. The manner in which these structures are formed is very interesting, and for the sake of any members of my audience who may have forgotten the *rationale* of the process I will venture to describe it.

And here I am reminded of an incident in the life of the celebrated French scientist, Ampère, at one time professor at the Lycée in Paris. The professor it seems when lecturing had a habit of fixing his attention upon some one person in his audience, and addressing himself exclusively to this particular individual. Upon one occasion the individual who was thus honoured happened to be a young man who, a not uncommon case, had a very high opinion of himself, and especially of his appearance, and conceiving that this had also struck the professor, felt flattered by his attention. Happening to meet Ampère one day in the street he ventured to accost him somewhat familiarly. The professor hesitated, and at length apologised for not being able to recognise the gentleman who had accosted him. "Oh," said the student, "You must know me, I am a member of your class at the Lycée, and every morning when you lecture, you fix your attention upon my face, and never remove your eyes until the lecture is finished." "Ha!" said Ampère, "that explains matters. I have a habit when lecturing of fixing my attention upon the least intelligent face present, and I go on explaining a point until I see that face brighten, and I then feel sure that if *that* individual understands me every one else *must*." Now of course I am not so impolite as to apply this anecdote to the intelligent audience I see before me, but I wish to ask you to excuse me if I seem too elementary in any of the explanations I may give you, as it is my desire that no one should go away from here at all mystified, and therefore you will I am sure pardon me if I occasionally inform you of what you already know.

Now as to the formation of these pendants and columns in limestone caverns. All natural water contains a small quantity of carbonic acid gas, which is a powerful solvent of limestone. All limestone rocks contain numerous joints or fissures through which water trickles, and as the water percolates through the rock, it, not simply because it is water, but because of the carbonic acid gas which it contains, takes up some of the lime in the form of what is known as *carbonate of lime*. A drop of such water trickles through the rock to the roof of the cavern and lingers a moment before it falls. While it lingers, part of the carbonic acid flies off and a small pellicle of limestone is left behind, attached to the roof. Then the drop falls upon the floor, and there the remainder of the carbonic acid gas evaporates, leaving upon the floor of the cavern a tiny crystal just beneath the little one on the roof. This process going on month after month, year after year, century after century, each little crystal grows, the pendant growing downwards from the roof, while a boss rises up to meet it from the floor, and in some cases the two meet to form a column. To the deposit on the roof the term *stalactite* is applied, while the deposit on the floor is termed a *stalagmite*, both words being derived from the Greek *stalasso*, to drop. There is no difference then, we see, between a stalactite and a stalagmite except one of position; the stalactite is on the roof, the stalagmite on the floor.

Limestone caverns, as I have already reminded you, are of particular interest on account of the pre-historic remains which have been discovered in them. In one instance we have very full descriptions of the manner in which these discoveries have been made, and I will therefore make no apology for giving you a brief summary of the results of these researches.

Running down to the sea at Torbay in Devonshire is a valley, and about half a mile up this valley another one runs into it from the west. Just at the junction of these valleys, there is a low, beautifully wooded, limestone hill. About 70 feet from the bottom of the valley, and 200 feet above the level of the sea, there is on this hill a low vertical cliff, and in this cliff are two openings which lead into a large cavern known as Kent's Hole or Kent's Cavern. In the year 1825 this cavern was visited by the Rev. J. MacEnery, a Roman Catholic priest then residing in the neighbourhood, who seems to have been a man of considerable culture and very liberal views. In his explorations he was surprised to find not only bones of extinct animals, but also, in conjunction with these bones, stone implements. His discoveries were, however, for a long time pooh-poohed, and so the matter lay dormant for many years, until in 1846 the Torquay Natural History Society expended twenty pounds in a systematic exploration of a small part of the cavern floor. A paper on the results of this exploration, which entirely confirmed MacEnery's statements, was read before the Geological Society; but again the matter was ignored. In 1858, however, a similar cavern was discovered at Brixham, on the opposite side of the valley, and a lease being taken of it, it was explored, and remains similar to those of Kent's Cavern were discovered in it. Finally, in 1864, a committee was appointed jointly by the British Association and the Geological Society to systematically explore such parts of the cavern floor as had not been previously interfered with. The committee consisted of such men as Sir Charles Lyell, Sir John Lubbock, Mr Boyd Dawkins, Professor Phillips, Mr Busk, Mr John Evans, Mr Vivian, Mr A. Sandford, and Mr Pengelly. The last named gentleman living in the neighbourhood, took the most active part in the superintendence of the excavations, and to his reports I am largely indebted for the information concerning them which I have now the pleasure of bringing before you.

The floor of the cavern is covered with a number of blocks of limestone, varying in size from small pieces weighing only a few ounces up to large blocks weighing several tons, and mostly cemented together by stalagmite. Beneath and between these is a layer of what has been named by the explorers *Black Mould*, the thickness of which reaches in some places more than a foot. This consists almost entirely of vegetable *débris*, introduced during violent storms. The next layer consists of stalagmite, and reaches a thickness of about five feet. This is succeeded by a deposit of what is known as *Cave Earth*, which has been excavated to a depth of about four feet. This consists of a light red loam containing nearly fifty *per cent.* of angular pieces of limestone. Below the Cave Earth is, in some parts of the cavern, another stalagmitic deposit, known as the *Crystalline Stalagmite*, and which reaches a thickness of twelve feet. Beneath this again is an older cave earth, known, for distinction's sake, as the *Breccia*, which consists of a darker material than the upper cave earth, and, moreover, is not adulterated with limestone. In one part of the cavern, near the entrance, beneath the upper stalagmite, was found a layer of charcoal about a hundred feet square, and named the *Black Band*. By way of recapitulation, I may say that, neglecting the limestone blocks, we have five deposits in the following order :—first, Black Mould, one foot; second, Granular Stalagmite, five feet; third, Cave Earth, four feet; fourth, Crystalline Stalagmite, twelve feet; and fifth, the Breccia, four feet. All these layers have been carefully excavated and their contents examined, with the following results. In the Black Mould were found pebbles of various kinds, whetstones, plates of slate (probably intended as covers for earthenware vessels), pieces of smelted copper, and various kinds of bone combs. In addition to these were found also spindle whorls, amber beads, charred wood, and flint flakes. Intermingled with these products of human industry were found animal remains consisting of bones and teeth of man, pig, dog, fox, badger, brown bear, short-fronted ox, red-deer, sheep, goat, hare, rabbit, water-rat, seal, birds, and fish; also shells of snails, limpets, whelks, oysters, cockles, mussels, pectens, solens, and cuttle-fish. All these animal remains are of the same species as those existing in historic times; none of them are extinct, and the implements found in connection with them are such as belong to Roman and pre-Roman times. Then we come to the Granular Stalagmite, and in that have been found remains of extinct animals, such as the elephant, rhinoceros, and hyæna, and with them bones and teeth of man, flakes and cores of flint, and stones of various kinds. In the Black Band, which you remember consists mainly of charcoal, and, it is surmised, was the place where the pre-historic men made their fire and cooked their food, were found flint tools, bone awls, pins, needles, and harpoons. With these implements were found burnt bones, and remains of the following animals, ox, deer, horse, badger, bear, fox, rhinoceros, and hyæna.

Digging down through the Cave Earth, they found in it stones from distant places, unlike any to be found in the neighbourhood, whetstones, hammer-stones, flint flakes, and bone pins and harpoons. In the same deposit were found bones and teeth of such animals as the cave lion, cave hyæna, mammoth, Irisk elk, glutton, grizzly bear, brown bear, rhinoceros, beaver, and reindeer, with some others. In the Crystalline Stalagmite remains of the bear only were found, and the same result attended the excavations in the Breccia beneath the stalagmite, but in both layers with these ursine remains stone implements have been discovered.

We see then that we have here incontrovertible evidence of the coexistence of man and animals which are now, not merely extinct as regards Devonshire, but which have altogether vanished from the face of the earth. It is necessary also to bear in mind that all the stone implements found in Kent's Cavern belong to the palæolithic or old-stone age.

To what then do these facts point? Do they give us any clue to the age of the implements which have been discovered, and therefore to the antiquity of man? Well, if you wish for an accurate measurement of that antiquity in years they do not, but that the date of man's appearance upon the earth must have been far earlier than that formerly assigned to it, they most decidedly do affirm.

As I gaze upon a lofty mountain, or a tall cathedral spire, I may not be able, without scientific measurement, to tell you its exact height in feet, but I can surely tell you it is very high, may even make a rough and tolerably accurate guess, and at least I can feel assured that it is much loftier than the surrounding hillocks or chimney-pots. Just so with the antiquity of these pre-historic remains; I do not for a moment pretend to even suggest their age with the accurate measurement of a chronometer, but wish you to take what I am about to say upon the subject, as that which the poet tells us all science is, "a blind man's guess," an attempt to gain some idea of the time when the men of Kent's Cavern hunted and fished in the southern parts of our island.

Let us begin with the cavern itself. You will remember we have in it two deposits of stalagmite, a material which is of necessarily slow formation, and beneath the older of these we have the remains of human industry. The formation of stalagmite is going on in the cavern at the present time, and we have evidence that it always has gone on, for most of the objects found in the Cave Earth are covered with a film of stalagmite, which further shows us that the deposit of the Cave Earth itself must have been intermittent; a sufficient time between each instalment must have elapsed for the stalagmite to have been deposited. It so happens that we have a remarkable clue to the rate at which the stalagmite is being deposited now, and we have no proof that it was ever formed more rapidly than at present. Kent's Cavern seems to have been a lion in the district time out of mind, and the British tourist has, as you know, a weakness for leaving a memorial behind wherever he goes. Doubtful of his ability to inscribe his name upon the pillar of Fame, he takes every opportunity of scratching it elsewhere. Now in Kent's Cavern there is, amongst others, an inscription which runs thus: "Robert Hedges, Ireland, Feb. 20, 1688." There is a yet older inscription, dated 1604, but let us take that of our friend, Robert Hedges. This inscription is on a boss of stalagmite, and is itself covered by a thin film of stalagmite, having a thickness of the twentieth of an inch. For nearly 200 years nature has been trying to obliterate that inscription and has not succeeded yet. Without attaching too great importance to it, let us for a moment consider this deposit as a measure of the rate at which stalagmite has been formed in Kent's Cavern, and see where it leads us. Two hundred years for the twentieth of an inch, that is 4,000 years for one inch, and we find in the cavern over 200 inches of this same material, which at the same rate would take us back 800,000 years before we come to the time of the Breccia, and even then men lived in Devon. But it is a perfectly legitimate objection, that this inscription may be a forgery, and may have been cut much nearer our own time than it represents itself to have been made. Very well, be it so! In 1825, MacEnery saw and described this inscription, and even then it was covered with a film of stalagmite. It is good then for fifty-six years at least, let us say fifty. Fifty years for the twentieth of an inch, 1,000 years for an inch, 200,000 years for 200 inches. Even with our amended data we are carried back 200,000 years! I am not, however, inclined to give very much weight to this kind of evidence, as the rate at which stalagmite may be formed is notoriously uncertain, and did it stand alone it would be comparatively valueless. But this is by no means the case. At the present time the floor of the cavern is seventy feet above the valley below. Now the Cave Earth can only have been introduced by storms (the only agency competent to do the work), when the floor of the cavern was about level with the surrounding surface of the land; therefore seventy feet have been excavated from the valley since the deposition of the Cave Earth. This, however, seems to have been not a primary, but a secondary excavation. The original valley was filled up with gravel and has since been re-excavated. But even the removal of a bed of gravel seventy feet thick must have occupied many, many centuries, and all this has been done since the era of the upper-cave earth.

But let us look for a moment at what was, meanwhile, going on elsewhere. In Denmark we have the peat bogs, and all the stone implements found there belong to the neolithic or new-stone age, and are unaccompanied by bones of extinct animals. Yet even in the peat bogs we find three distinct varieties of forest trees anterior to the beech tree which now flourishes there. The oldest of these varieties, the Scotch fir, will not grow in Denmark at all in the open air, at the present time. Just think of the enormous time required for the growth, and ultimate dying out, of three distinct species of forest trees, each requiring different conditions of soil and climate, and then remember that before the time of the oldest Scotch fir in these bogs, the last palæolithic man had died out from the south of England!

Then, again, we have the evidence derived from the bones which have been found in juxtaposition with the stone implements in Kent's Cavern, and such animals as the reindeer, the woolly-haired rhinoceros, and the mammoth, indicate the existence of a very cold climate. Now you are doubtless aware that many thousands of years ago there was such a period of great cold, known as the Glacial Epoch, and we have reasons to believe that that epoch was not an unbroken reign of ice and snow, but that there were interregna of much more genial climate. It has been thought by some that man's appearance upon the earth preceded this Glacial Epoch; but we have no evidence at present of the truth of this hypothesis. We have, however, good reason to believe that man was on the earth at least as early as the last genial interval in the Glacial Epoch. If then we can approximately settle the date of this epoch, we shall have some clue to man's antiquity. And here we must call in to our aid the astronomer.

As every one knows, the earth revolves round the sun in an orbit or path, which is not quite circular, but is elliptical. This *excentricity* of the earth's orbit is constantly, though very slowly, varying; sometimes the orbit is more, sometimes less, elliptical. At present the excentricity is decreasing, the orbit is becoming more circular. Astronomers, however, tell us that a period of very great excentricity began about 240,000 years ago, and terminated about 80,000 years since. At the present time when the earth is in *perihelion*, that is at its shortest distance from the sun, it is three millions of miles nearer that luminary than when it is in *aphelion*, that is, at its greatest distance from the sun. When the excentricity was greater than at present the difference in the distances from the sun at aphelion and perihelion would, of course, also be increased. At present our winter occurs when the earth is in perihelion, and this has the effect of indirectly ameliorating the coldness of that season. But here let us be cautious not to fall into an error. The nearer the earth is to the sun, the faster it moves, and *vice versâ*, so that during a given season the total amount of heat received by the earth will be the same, whatever its position in its orbit; decrease in the intensity of the sun's rays being compensated by increase in the time of the earth's exposure to their influence. But our winter occurring in perihelion, shortens its duration, owing to the increased speed with which the earth hurries through this part of its journey, and at present our winter is eight days shorter than that of the southern hemisphere, which occurs in aphelion. Now suppose that during this period of great excentricity, the conditions of the northern and southern hemispheres were, in this respect, reversed; suppose, that is, that our winter occurred in aphelion, how would that affect its intensity? Well it would be from sixteen to twenty-six days longer than the summer, and that would lead to a greater accumulation of snow and ice in the northern hemisphere during its winter. Its summer would occur in perihelion, it is true, but then the sun's rays do not heat the air through which they pass, *that* is heated by the warm earth radiating its heat to the air above it. If the ground were covered with ice and snow the heat of the sun would be absorbed in melting and evaporating the ice and snow, and the great amount of evaporation, again, would tend to make the atmosphere misty and cloudy, and so the sun's rays would be to a great extent cut off. These causes combined would have the effect of intensifying the cold of winter, and of leading to an immense accumulation of snow and ice. The warm ocean currents, moreover, which now flow from the equator northwards, would be turned backwards by the more violent northerly winds, and this, again, would intensify the cold of the northern hemisphere.

But you ask, "Is it possible for the winter of the northern hemisphere to occur in aphelion?" Yes, it is. As you know, the vernal equinox occurs now about the 20th of March, but every year the earth has this same equinox about twenty minutes earlier than it did the preceding year, and consequently the point in the earth's orbit at which the equinox occurs is gradually shifting backwards, and this tends to bring about the equinox, and, of course, the other seasons also, at every point of the orbit, the entire cycle being performed in about 26,000 years. Consequently winter must have occurred in our hemisphere in aphelion more than once during the period of excentricity to which I have referred, and this must have had the effect of producing exactly such a condition of climate as geological evidence shows us did at one time exist. It is calculated that during this period the average temperature of the northern winter must have been from thirty-eight to twenty-six degrees colder than it is at present. We are justified then in saying, that the Glacial Epoch probably occurred at this time, and began about 240,000 years ago, lasting till about 80,000 years ago. If man, as we have every reason to believe, came upon the scene not later than towards the close of this epoch, his antiquity must date back at least 80,000 years.

This is a part, and but a small part, of the evidence of man's great antiquity; but time forbids me to dwell upon it longer, and I must leave you to follow out the evidence for yourselves, and so form from it your own conclusions. If anything I have brought before you this evening has startled you, or apparently interfered with long cherished beliefs, do not, therefore, hastily put it on one side, and still less accept in blind faith anything I may have said. Unreasoning faith is in the student of Nature the one unpardonable sin; therefore, in conclusion, let me ask you to examine conscientiously and carefully into the facts, and form from them an unbiased and therefore reliable conclusion; and doing this, I feel sure that whatever system of philosophy you may, as the result, adopt, you will find even yet, that there are "more things in heaven and earth than are dreamt of" in it.

IV.

VOLCANOES AND CORAL REEFS.

IN the modification of our globe the force of heat has at all times played an important part, and perhaps its most striking phase is that of volcanic action, the phenomena connected with which still form prominent features in the grand panorama of Nature.

Whatever may be the source of the heat of the globe, it is matter of common knowledge that somewhere beneath its surface a quantity of heated material exists, and that the efforts of that material to burst its rocky prison result in the phenomena of earthquakes and volcanoes. As to the manner in which these materials are disposed beneath the earth's crust there has been much dispute, and the matter, even now, can scarcely be considered to be set at rest. According to the older view, the earth consists of a hollow shell, from one to two hundred miles in thickness, the whole of the interior being in a highly heated molten condition. The more modern theory is that the earth is more or less solid throughout, but that here and there, within a few miles of the surface, there exist isolated accumulations of heated material, which have a constant tendency to break through the overlying rocky crust and escape to the surface.

In favour of the first of these theories we have the undoubted fact that the temperature of the earth's interior steadily increases in all parts of the globe as we get nearer the centre. In all mines and other excavations of the earth's interior it is found that for the first ninety feet, or thereabouts, below the surface the temperature of the crust of the earth varies with the climate and with the seasons; but that below this *zone of variable temperature*, as it is termed, the temperature is found to be the same throughout the year, and that it increases at about the rate of one degree Fahrenheit for every sixty feet of descent into the interior. Local circumstances, of course, affect this progressive increase; but, taking a series of observations in various parts of the globe, the figures are, on the average, those just stated. Another argument in favour of the older theory as to the condition of the earth's interior is the wide-spread existence of volcanoes and earthquakes, and the identity of the materials ejected by volcanoes wherever they exist. Again, it is urged that if the progressive increase of temperature noticed above be maintained, the heat will be so great at a depth of one or two hundred miles beneath the surface that even the most refractory substances known must infallibly succumb to its influence, and assume the liquid, if not the gaseous condition—platinum, the metal which has the highest melting point, being fused at a depth of about thirty-five miles. Against these arguments in favour of the fluidity of the earth's interior numerous objections have been urged. Amongst others may be mentioned the following. The centres from which earthquake action originate are, as recent research has conclusively shown, situated but a few miles—certainly not more than thirty—beneath the surface. Again, were the material ejected by volcanoes obtained from a common source, upon the principle of the equilibrium of fluids, the lava in the craters of volcanoes in all parts of the world should stand at the same height, which it most certainly does not. Finally, if the interior of the earth be entirely molten, the same influence which produces tides upon the surface would produce tides in the interior, and these would infallibly burst through a crust less rigid than one of the hardest steel. These objections are of great weight, and, on the whole, it is more probable that the modern theory, which supposes the globe to be tolerably solid, is the correct one; but, however this may be, we will now turn our attention to the nature of the phenomena to which the earth's internal heat, however disposed, undoubtedly gives rise. The nature of volcanoes and earthquakes may best be understood by considering briefly some of the most important examples of each.

The district of the Mediterranean Sea has long been celebrated for its volcanoes, and one of the most picturesque is undoubtedly that of Stromboli in the Lipari Islands, which was in much the same condition as at present, even in Homer's day. Continually emitting flames, ashes, and lava, it forms a natural lighthouse, illuminating the sea far and wide with its ruddy light. The opening from which the lava comes is on the side, and not upon the top of the mountain.

If we examine an imaginary vertical section of a volcano we find that it consists of a conical hill or mountain, in the top of which is a basin-shaped depression, the *crater*. Running up the centre of the mountain, and opening into the crater, is the main chimney, or vent, while numerous fissures exist in the sides of the cone, some of which do, and some do not, reach to the surface. From those which reach the air streams of lava flow during an eruption, while similar molten material is injected into those fissures which are entirely subterranean. In the course of time this latter material solidifies, and the action of the atmosphere wearing away the softer overlying rocks, the cooled lava is left in the shape of walls, or "dykes," as they are termed, sometimes running for miles across a hilly country, which was in former times volcanic. Much less frequently, the lava is softer than the surrounding rocks, and if in any way the atmospheric agents gain access to it, it decays, and leaves grooves and hollows behind it. From this it will be seen that the term "burning mountain," so frequently applied in popular phraseology to volcanoes, is a misnomer. The volcano is not itself burning, but only the material which it ejects: a volcano is simply a chimney, or vent, by which subterraneous heated material finds its way to the surface.

To account for the origin of volcanic cones two theories have been propounded. One, known as the *Elevation theory*, supposes that the cone is formed by the swelling-up of the rocks into a bubble-shaped heap, which bursts and gives rise to the cone and crater. The other theory, known as the *Eruption theory*, supposes that the cone results from the gradual piling-up of the ejected material round the central orifice, and the manner in which the rocks of a volcanic cone are disposed most decidedly favours this conclusion, which is now generally accepted as the correct one. The materials ejected in a volcanic eruption are solids in the form of blocks of rock, varying in size from small pieces the size of a nut up to blocks weighing several tons, rock-ash, and extremely fine dust. Liquids are represented by molten rock or lava. Gaseous materials are emitted in the shape of steam, sulphuretted hydrogen, and other gases.

One of the most remarkable volcanoes in the world, whether we consider its present condition or its past history, is Vesuvius, in the south of Italy. Up to about the year A.D. 79 this mountain had given no signs of activity, and was considered to be quite extinct; vines covered its slopes, and its crater was covered with grass and shrubs. In this year, however, the mountain began to give signs of uneasiness; tremblings of the earth were frequent, and earthquakes, gradually increasing in force and frequency, culminated in that memorable eruption which overwhelmed the populous cities of Herculaneum and Pompeii, which, after nearly eighteen centuries of oblivion, have in modern times been brought again to light. Pliny the younger, as every one knows, wrote a very complete account of this eruption to

Tacitus the historian, and, as the phenomena agree very well with what has subsequently been noticed in various parts of the world, I will refer to it at length.

For some days before the eruption a huge cloud, the shape of an Italian pine tree, flattened out at the top something like an umbrella, hung over the mountain. This cloud, which is a common feature in volcanic eruptions, is not, as popularly supposed, composed of smoke, but consists of an immense quantity of very fine dust and steam. It has been estimated that in such a cloud, at any one moment, as many as twenty thousand cubic yards of water are held in suspension. From this cloud immense showers of dust fell upon all the surrounding country, including the cities of Herculaneum and Pompeii. Then, when a considerable deposit of this fine dust had accumulated, the steam becoming condensed came down in torrents of rain, converting the dust into a fine liquid mud, and by a flood of this so-called *water-lava* (*lava d'aqua*), both Herculaneum and Pompeii were overwhelmed. No true lava reached these ill-fated cities at that time, showers of ashes and torrents of lava d'aqua alone effected the work of destruction, and although Herculaneum is at present buried beneath true lava, it is quite certain that none of it is older than the tenth century. The penetrating character of the fine mud enabled it to enter the smallest cavities, and to this fact we owe the preservation of so many interesting memorials of life in a fashionable watering-place eighteen centuries ago. Since this historic eruption Vesuvius has been in a state of constant activity, and several very terrible eruptions have occurred. In 1829 a new crater (the present one) was opened in the old one, which was of much greater extent, and some two thousand feet deep.

A very remarkable volcano, and one much loftier than Vesuvius, is Mount Etna, on the eastern coast of Sicily, which reaches a height of between ten and eleven thousand feet. This mountain is divided into three regions, at its base is an extremely beautiful and fertile region, above this a belt of forest some seven miles in breadth, and above this again a barren desert region covered with snow through the greater part of the year. The central cone rises from the centre of this district, above which it towers to a height of nearly eleven hundred feet. This central cone is not, however, the part of the mountain which displays the greatest volcanic energy; we must look for that in the forest region. From this region arise over seventy volcanic cones, from which at various times immense streams of lava have flowed. Mount Etna thus forms a kind of compound volcanic mountain.

As a contrast to such a compound volcano we have in the Phlegræan Fields near Vesuvius a small volcanic mountain, or rather hill, which is at present to all appearance extinct, but the history of which is very curious and interesting. Until the year 1533 there existed on the spot now occupied by this volcano a town named Tripergola. In this year numerous earthquake shocks were felt in the neighbourhood, and at length the ground suddenly sank fourteen feet. Quickly it rose again like an immense bubble and then, as bubbles will, burst, forming a basin-shaped depression with an aperture in the centre, from which flames, steam, and volcanic-ash were emitted, and in twenty-four hours the city of Tripergola had given place to a mountain a mile and a half in circumference at its base, and 440 feet in height. This mountain is known as Monte Nuova, and since its formation it has shown no signs of volcanic activity, its sides and crater being at the present day covered with grass.

Here Nature was as it were caught in the act of forming a volcano, and we see the nature of the entire process from beginning to end. Other similar instances are also known. In Mexico there is a chain of six volcanic peaks, known as the Jorullo, and these were upheaved in a few weeks, their formation being preceded by earthquakes, and the opening of an enormous chasm through which were ejected the materials of which the peaks are composed; the loftiest of these is sixteen hundred feet in height.

A region which has always been noted for its grand exhibitions of volcanic energy is Iceland, and during some of the most terrible of these eruptions the discharges of lava have been enormous, almost beyond conception. Hecla, in the south of the island, is the loftiest peak, being about four thousand five hundred feet in height. Nearly fifty eruptions of this mountain are recorded, the most terrible being one which took place in 1783. Skaptar Jokul, a neighbour of Mount Hecla, however, carries off the palm for enormous energy. In 1783, during an eruption it discharged more lava than the Nile discharges water in a year. This was emitted in two enormous streams, one fifty miles long and twelve miles wide, the other forty miles long and seven miles broad. Altogether Skaptar Jokul in this single eruption poured out, as Sir Charles Lyell estimated, sufficient lava to fill up all the valleys and cover up all the hills from London to Gloucester with a coating from one to five hundred feet in thickness. From the effects of this eruption thirty thousand people perished. Streams of lava are popularly supposed to be in appearance like streams of liquid fire, but this is to a great extent a delusion. Seen at night, immediately they issue from the volcano, they do have such an appearance, but lava cools very quickly, and a crust is soon formed over the streams which generally look more like rivers of mud than anything else, especially when, as is generally the case, they are covered with ashes and dust. The crust which forms over the lava is a very bad conductor of heat, and consequently while the top of a stream is hard and firm, the interior retains for a long time its heated, and even molten condition.

Two very striking volcanoes are Mounts Erebus and

Terror, which are found in the gloomy Antarctic regions. These giant warders of the southern continent illumine with their hideous light those desolate regions of perpetual ice and snow. Mount Erebus, the loftier of the two, reaches an altitude of twelve thousand four hundred feet.

The Andes, which form the back-bone of South America, are mostly volcanic, and one of the most remarkable peaks is Cotopaxi, which, rising to a height of about nineteen thousand feet, has its summit covered with perpetual snow. Above this enormous peak the flames rise some three thousand feet, forming a most imposing spectacle. A peculiar feature of the South American volcanoes is the entire absence of lava, solid and gaseous materials being alone emitted.

The largest volcano in the world is undoubtedly Kilauea, in the Sandwich Islands. It is in a state of constant activity, and at intervals suffers eruptions of a very magnificent and startling character. The floor of the crater is a mass of black seething lava, several square miles in extent, from which numerous columns of smoke and sulphureous gases ascend. When in more active eruption the crater becomes converted into a sea of fire, while fountains and cascades of flame are tossed high in the air, or fall over tremendous precipices. The sight is described by travellers as being of the most awful and fascinating character, and one to which no description can do justice; the crater is ten or twelve miles in circumference.

Volcanoes are not confined to dry land, but frequently occur beneath the sea. The great eruption of Skaptar Jokul in 1783 was heralded by the sudden upheaval of a small island between Iceland and Denmark. To this the King of Denmark immediately laid claim, but Father Neptune speedily resented this attempt to interfere with his "ancient solitary reign," for in a few months it disappeared beneath the ocean as suddenly as it had been upheaved.

A fine example of a submarine volcano is to be found in the island of Santorin, in the Grecian Archipelago, which with the neighbouring islands is arranged in a form suggestive of the crater of a volcano. These islands have been thrown up by volcanic action at various dates, the oldest of them having been thrown up so far back as one hundred and ninety-eight years before the Christian era.

In addition to such active volcanoes as those described above, and of which there are altogether nearly four hundred, there are in many parts of the world the remains of volcanoes which are totally extinct. Auvergne in France, and the Eifel in Germany, afford numerous instances of extinct volcanoes.

Between the two great classes of volcanoes, active and extinct, we have cones which emit materials of a less highly heated character than those emitted by such active volcanoes as Vesuvius. These occur in districts where volcanic energy is evidently dying out, and usually emit either warm mud, sulphureous gases, or steam. They are usually hills of low elevation only, and the materials ejected vary in temperature from that of boiling water or higher, down to a temperature but little above that of the surrounding air. A good example of a series of mud volcanoes is found in the Crimea, and numerous examples of air volcanoes occur in South America, near Quito.

Closely connected with volcanic energy are the numerous hot wells and boiling springs which occur in many parts of the world. The most celebrated boiling springs are the Geysers of Iceland. In the northern part of this island more than fifty geysers may be seen in the space of a few acres. The largest of these is the Great Geyser, which rises from a mound of flinty earth about thirty feet high and two hundred feet in diameter. On the top of this mound is a basin sixty feet wide and seven feet deep, and in the centre of this basin is the opening of a pipe which leads into the earth. Here we at once perceive the likeness existing between a geyser and a volcano. The basin and pipe are lined with a coating of siliceous material, and huge crystals of the same substance, in appearance not unlike cauliflowers, are scattered round the basin. Small eruptions of the geyser occur about every three hours, but the grandest displays occur only once in thirty hours. These are preceded by a hollow rumbling noise, and by loud subterranean explosions which shake the earth. Suddenly a huge column of boiling water and vapour shoots up, with a somewhat fluctuating motion, to a height of eighty or ninety feet. From this central pillar numberless smaller jets rise to a much greater height, and when the steam is blown aside by the wind, the central column of water is seen to spread itself out at the top in the same manner as the cloud does in a volcanic eruption. At intervals the column of water suddenly subsides, but is immediately shot up again with an accompaniment of subterranean explosions and rumbling noises. The whole eruption lasts about ten minutes, and at its close the water in the basin is found to be nearly boiling, while that in the pipe is many degrees above the boiling point.

The largest known geyser is the Giantess of the Yellowstone River in North America. In this case the crater is on level ground, and not on a hill, as is most generally the case. The displays last twenty minutes, and the main jet of water and steam rises to a height of sixty feet, while smaller jets reach a height of about two hundred and fifty. In all eruptions of geysers the termination of the display is heralded by a jet of steam unaccompanied by water.

Besides these absolutely boiling springs, others occur in great abundance in which the water is hot or merely warm. Of hot wells, the most remarkable are those on Gardiner's River, a tributary of the Yellowstone in North America. These are situated in a district covered with volcanic ashes, and emit suffocating sulphureous vapours.

Geysers, boiling springs, and warm wells undoubtedly have their origin in the same subterranean heat as that which gives rise to volcanoes. The explanation of the intermittent eruptions of the geysers is very simple. The pipe opening into the basin or crater leads down into the earth, and, bending nearly at right angles to itself, communicates with a subterranean reservoir in the heated rocks. Water percolating through the overlying rocks gradually accumulates in this cistern. There it becomes heated and partially converted into steam, which steam, having its pressure increased by the heat of the surrounding rocks, presses upon the surface of the water and forces it up the pipe into the crater of the geyser. During the interval between the two eruptions the water is accumulating in the cistern, and steam being formed.

A well-known phase of heat action is seen in those disastrous phenomena—earthquakes. With the general features of these occurrences we are all familiar from the reports of eye-witnesses, though, happily, we have in this country no personal experience of them. As a general rule they are heralded by signs similar to those which precede a volcanic eruption. The air for days before is heavy and stifling, tremblings of the earth, causing nausea and giddiness in man and animals, are felt, subterranean noises like the clanking of chains or the discharges of artillery are heard, and storms accompanied by thunder and lightning frequently occur. Then comes the final outburst, the earth is upheaved, houses and buildings of every kind are thrown down, and in a few minutes the work of destruction is complete.

One of the most terrible visitations of which we have any record was the earthquake by which, on the first of November 1755, the handsome city of Lisbon was destroyed. Contrary to common experience, this earthquake was not preceded by any of the usual signs. The sun rose bright and beautiful on that eventful morning, everything wore its accustomed aspect, men went about their business or their pleasure without any foreboding of ill, when suddenly the outburst came, and in a few moments the stately city was changed into a shapeless heap of tottering ruins, and sixty thousand of the inhabitants were, without warning, hurried into eternity. A peculiar feature of this eruption was the sudden submergence of a large marble quay, which had recently been constructed at great expense. Alarmed by the falling buildings, a large number of the inhabitants rushed for safety to the quay, which soon became crowded, when suddenly it sank with every soul upon it, and not a vestige of it was ever seen afterwards; it disappeared, and literally

> "Like an insubstantial pageant faded,
> Left not a wrack behind."

Another peculiar feature which frequently accompanies an earthquake was also witnessed on this occasion. The Tagus suddenly receded from its banks, leaving the bottom of the river dry, and then as suddenly swept in again with tremendous violence, reaching the central parts of the city, and adding yet another drop to the overflowing cup of its inhabitants' calamity. This earthquake was felt over a very wide area. The actual shock was felt in the north of Africa, and in the south of Norway, Sweden, and the British Islands, while secondary effects were experienced in North America and the West Indies. In the latter district the usually small tides were suddenly augmented, and the sea was churned up until its waters became as black as ink.

Another terrible earthquake, or rather series of earthquakes, was that of Calabria, which, commencing in 1783, lasted nearly four years. During this terrible period about sixty thousand persons perished, and the destruction of property was equally disastrous. Many curious effects in the alteration of the level and position of the land were observed. It is usually considered that the American story of one man's field being placed by an earthquake upon the top of that belonging to another is a choice specimen of humorous mendacity, but in the Calabrian earthquake several instances of this actually occurred; portions of land were removed bodily from a higher to a lower level. In one place a chasm was opened in the side of a hill; in another a mass of land was deposited in a river and blocked up its course, the removal being effected so gently that trees were left standing and continued to grow in their new situation.

In 1822 an earthquake occurred in Chili, in the western coast of South America, and affected about twelve hundred miles of sea coast, permanently changing the level. For hundreds of miles the sea coast was raised, and many places which formerly afforded anchorage for large vessels were, after the earthquake, too shallow for that purpose.

In 1819 an earthquake occurred in a district known as Cutch, at the mouth of the Indus, and in this case the result was a general lowering of the land, though in places a little distance away an elevation of the land took place—the land, in fact, was bent and crumpled up. Numerous theories have been propounded to account for earthquakes and volcanoes, but the one now generally received, and which certainly seems to fully and clearly explain the phenomena, is due to Mr Mallet. Water is undoubtedly at the bottom of the matter, for fish and other aquatic objects have been thrown out from the craters of volcanoes. In the cooling of the earth, which takes place unequally in different parts, some portions of the earth's crust become harder and denser than others, and so we get lines of strength and lines of weakness. As the crust cools considerable pressure must be exerted upon the central portions, and pressure means heat. This heat has in many parts been sufficient to liquefy the rocks, and produce subterranean reservoirs of lava. Water percolating through the rocks reaches these reservoirs, and becomes converted into steam, the pressure of which soon becomes sufficient to rend the earth's crust at its weakest parts. If the resistance be very great, an earthquake occurs; if not so great, a volcano is the result—an earthquake being an unsuccessful attempt to establish a volcano. Thus we see that the agency which probably causes these tremendous convulsions of nature is identical with that which works our machinery, and serves so efficiently the purposes of locomotion—steam. And we must remember, too, that just as our steam boilers require a safety valve, so does the subterranean vapour require some outlets, and these it finds in those great natural safety valves, earthquakes and volcanoes. Terrible as these phenomena appear, disastrous as are their effects, they, like everything else in nature, have a beneficent purpose to fulfil. In addition to giving vent to the internal heated material, these phenomena have, by twisting and tilting over portions of the earth's crust, brought within man's reach a quantity of mineral wealth, which would otherwise have lain far beneath the surface, and beyond his ken.

It is not improbable that the connection between volcanoes and coral reefs is not readily apparent to all, but a little consideration will show that there is a connection of an important character. The white arborescent material which we see in museums and occasionally in cabinets in dwelling-houses is, as every one knows, the product of a minute animal, the coral polype, which labours incessantly beneath the seas in the regions of eternal summer. The red material which is made into gum-rings and necklaces for the use of the rising generation, and which is also termed "coral," is not the most important kind, and our description does not in every way apply to it, but to the white variety only.

A good idea of the coral polype may be gained from a consideration of the much more familiar "sea-anemone," to which it is distantly related. Every visitor to the sea-side has seen at low tide the short cylindrical, leathery-looking sea-anemones attached to the rocks, their tops surmounted by a circlet of fine filaments or "tentacles," which gives it that flower-like appearance which suggested its name. If we examine one of these little animals carefully, we see that in the centre of the circlet of tentacles is an aperture, the mouth, which leads into a blind sac, the digestive sac, the single aperture at the top serving both for an inlet for nutritious substances and as an outlet for waste material. When anything good to eat comes within range of the tentacles they close round it and draw it into the digestive cavity, where it undergoes processes analogous to those which take place in our own bodies, whereby the nutritious portions are rendered fit for absorption into the general system. Should the animal get hold of something too large for the capacity of its stomach, it gets out of the difficulty by splitting itself in two, each half growing into a perfect animal. In addition to thus multiplying by "fission," the little coral animals multiply by "budding." A small bud grows out of the side of the body, and gradually assumes the shape of the parent stem, from which it sometimes becomes detached, and begins life on its own account. A third method of multiplying is by the production of eggs, which are hatched, and the young passed out of the mouth. The young are small oval bodies, provided with numerous hair-like vibratile filaments, termed "cilia." By means of these cilia the young polype swims about, often travelling for some distance from its parent, and at length, having apparently sown its wild oats, it loses its cilia and settles down upon the bottom of the sea. There it anchors itself permanently, and, continuing to grow, gives off buds, and these buds give off others, so that you soon get a kind of living tree, the open mouths of the polypes, with their circlets of tentacles, representing flowers. These coral polypes have the power of extracting from the sea-water in which they live carbonate of lime. This they deposit in the interior of their bodies, until a skeleton, which is a complete model in carbonate of lime of the colony of polypes, is formed. When the polypes die the soft parts decay, and the skeleton is left in the form of coral. In some cases the skeleton acquires a red tint, and forms red coral, but in these colonies the skeleton is far less complete than in the white variety, where there is a skeleton for each individual polype, as well as for the common stem. As successive generations of polypes die, others build upon their skeletons, and so in the course of ages immense deposits of coral have been formed.

On examination of the various deposits of coral in different parts of the world it is found that they occur in three forms, known respectively as "fringing reefs," "barrier reefs," and "atolls," or coral islands. The island of Mauritius in the Indian Ocean affords a good example of the first variety. All round the island is a kind of terrace formed entirely of coral, extending about a mile from the shore, and at the edge this rises into a kind of rim over which the waves dash and foam. Inside the reef the sea is very shallow, but outside it suddenly deepens. The coral polypes flourish best on the edge of the reef in the surf, but they also live and work beneath the surface down to a depth of about a hundred and fifty feet, beyond which it is certain that they cannot live. The space between the reef and the land is termed the lagoon, and the bottom of this is formed by a kind of coral mud formed by the waves dashing over the natural breakwater formed by the edge of the reef, detaching fragments and grinding them to powder. Numerous examples of the fringing reef occur in other parts of the world, but the one cited above is perhaps the best example of a simple reef. Barrier reefs are often of enormous size, one on the east coast of Australia being more than eleven hundred miles long, and from one to several miles in width. This reef is separated from Australia by a channel about a hundred and fifty feet deep, while outside the reef the sea is two or three thousand feet deep.

The third variety of coral reef, the atoll, consists of an incomplete ring of coral rising up in the middle of the ocean, apparently unconnected with any land. In its centre is a shallow lagoon, and the top of the reef is covered with beautiful vegetation, sprung from seeds dropped by birds, or carried thither by winds. On one side of the reef is an opening, and through this ships can obtain entrance to the lagoon, which forms an admirable natural harbour. Outside of the reef the soundings rapidly increase in depth, until at the distance of less than a mile they reach over three thousand feet. If the ocean floor were laid bare these atolls would be seen to rise up as huge conical hills with indented tops, much resembling the crater of a volcano.

The occurrence of these three varieties of coral reefs was for a long time a puzzle to scientists. In spite of the fact that the coral polypes cannot live at a greater depth than from one hundred and twenty to one hundred and fifty feet beneath the surface, we have these immense masses of coral thousands of feet in thickness. After several attempts to solve the problem, the question was at length set at rest by that great naturalist Charles Darwin, who has rendered such valuable service to the cause of science. In a work upon the subject, Darwin has fully expounded his theory, and it is roughly this: The areas where barrier reefs and atolls exist are, and have been for ages, slowly sinking, and the polypes in their building have kept pace with this subsidence. If we assume the existence of an island in a coral sea, we have no difficulty in understanding how the polypes would build upon it a fringing reef, the depth of the coral below the surface never exceeding a hundred and fifty feet. Now suppose that the island slowly sinks, and that as it sinks the polypes continue to build. It is clear that in time we should have a barrier reef at some distance from the land, with a shallow sea inside and deep ocean beyond. Let the sinking continue until the island is completely submerged and you will have an atoll, a circular reef of coral unconnected with visible land, and with a shallow lagoon in the centre. That this hypothesis is tenable has been subsequently shown by the discovery of the fact that the land is in many other parts of the globe either slowly rising or slowly sinking. The northern part of the coast of Scandinavia is known to be slowly rising, while the southern portion is slowly sinking. The eastern portion of the South American continent has for ages been undergoing gradual upheaval, as shown by the numerous raised beaches which exist there, with the remains of marine animals, such as barnacles, clinging to rocks far inland, as we now see them on cliffs upon the sea-coast. In fact, the land which we are so accustomed to refer to as the type of everything fixed and unchangeable, is in constant though gradual motion, rising here, falling there, and its surface like that of a troubled ocean seldom entirely sinks to rest. A further proof of the correctness of Darwin's hypothesis is to be found in the fact that volcanoes exist only in districts which are either stationary or slowly rising, and are never found in company with atolls. The cause of these gradual movements of the earth's crust is undoubtedly to be found in that same internal heat which gives rise to the more sudden and violent disturbances, and thus we have a direct connection shown between volcanoes and coral reefs; the force which produces the former renders the existence of the latter possible.

At one time it was customary to think that the present condition of the globe had been brought about by a series of catastrophes, but it now seems highly probable that the work has been mainly effected by the more gradual movements, and the lesson we learn is that it is not always the most obvious and startling of nature's works that are the most important, but that the most effective are those which work in silence, unheeded or unseen. Not only when with terrific violence the imprisoned gases burst their rocky prison-house and the earth seems to stagger beneath the blow; not merely when some fierce tornado or desolating hurricane sweeps with resistless energy across some fair region of the earth, spreading terror and desolation in its path; but in the calmest and softest summer's day, in the tiniest of ocean's wavelets that ripple on the shore, do

> "The giant ages heave the hill
> And break the shore, and evermore
> Make and break and work their will."

V.

ATOMS AND MOLECULES.

THE subject to which I beg to invite your kind attention this evening affords an example of how in the scientific as in the fashionable world, history repeats itself. About three hundred years before the Christian era, the Greek philosophers enunciated in a crude form a theory of atoms, and again at the commencement of the present century—almost within living memory—John Dalton of Manchester established upon a firm, because scientific basis, his well-known Atomic Theory.

According to the old philosophers all matter was supposed to be composed of ultimate particles or atoms in constant and rapid motion amongst themselves, falling towards and rushing against each other, and occasionally uniting to form compound bodies. The ancients further supposed that these atoms were provided with claws or hooks by which they could become mutually attached. The movements of the atoms were supposed by these old philosophers to be quite erratic, and their occasional union quite a matter of chance; in fact, the formation of any new body whatever, from a tiny crystal to a huge planet like our own, was regarded as being merely "a fortuitous concourse of atoms." Such were the crude ideas of the old philosophers, and although they were to some extent modified and improved as time went on, the atomic theory remained at a standstill for many centuries, and was generally ignored by more modern philosophers, who regarded it as an exploded idea. So matters went on until the time of Sir Isaac

Newton, who, in his enunciation of the law of gravitation, familiarised the scientific world with the conception of that phase of force which is known as *action at a distance*, and showed how it was possible to have every particle of a heavenly body separately attracting every particle of matter in the earth without the necessity for any intervening material bond of union. This conception applied to the imaginary atoms of matter did away at once with the necessity for the claws or hooks which the ancients supposed them to possess, and so another step forward was made. But in Newton's day chemistry as a science had no existence, and so that great philosopher was unable to apply his new theory to the explanation of the phenomena which belong to its domain.

But in the latter end of the last century there arose in the city of Manchester another of those master minds which play the part of pioneers in the onward march of human knowledge. This was John Dalton, who was born September 5th, 1766, the son of humble Quaker parents, and who subsequently obtained his living as a schoolmaster and science teacher. With a soul far above the drudgery of his daily occupation, Dalton applied his spare time first to the study of natural science and then to original research, and in November 1802 he read his first paper before the Literary and Philosophical Society of Manchester. In this paper which was entitled, "An Experimental Enquiry into the Proportion of the several Gases contained in the Atmosphere," are to be found the germs from whence sprung his subsequent grand discoveries. In it he tells how experiment has conclusively shown him that a gas, known as nitric oxide, combines with two distinct proportions of oxygen to form two different compounds, the proportions of oxygen by weight being in the ratio to each other of one to two. Moreover, Dalton showed that it is quite impossible to obtain a compound of these two gases which contains an intermediate weight of oxygen; it is impossible for instance to obtain a compound of nitric oxide with oxygen which shall contain one and a half times as much oxygen as the lowest oxide. This discovery was the starting-point of a brilliant series of experiments which led to most important results—experiments, let us bear in mind, carried out by a poor schoolmaster with the simplest and rudest apparatus, much of it made with his own hands.

In the year 1804 Dalton experimented with two other gases, carbonic oxide and carbonic acid gas, better known respectively as *fire damp* and *choke damp*. Now these two gases are in many respects totally dissimilar, so that there can be no doubt that they are perfectly distinct bodies, and not different conditions of the same substance. Both are invisible gases, but whereas carbonic oxide will burn with a blue flame—you see it so burning sometimes above a clear fire—carbonic acid gas not only will not take fire, but extinguishes a lighted taper or candle placed in it. Both these gases, as Dalton showed, contain carbon and oxygen, but carbonic acid gas contains exactly twice as much oxygen as carbonic oxide does. In other experiments Dalton compared two other gases, one known as marsh gas, and the other as olefiant gas. Both these gases are composed of carbon and hydrogen, and Dalton showed that the amount by weight of carbon which is contained in olefiant gas is exactly twice as much as that contained in marsh gas. These experiments were extended by Dalton and those who came after him to all the known elementary substances, and the result of their labours has been to show that the same thing holds good throughout the entire series, and that there exists a natural law which is termed the law of multiple proportions. Technically stated this law runs thus:—"All substances combine with others in a definite proportion by weight, or in a simple multiple of that proportion." In other words, there is for every substance a definite number which represents its combining weight, and when substances combine together, the quantity of each in the new compound will be that number, or twice, three, or four times that number. Let me illustrate this by a striking example, for it is important that we should be quite clear about this fundamental principle of the science of chemistry. The element nitrogen forms with oxygen five distinct compounds, and analysis shows us that while the quantity of nitrogen in each is the same, the quantity of oxygen present differs in each case. In the first we have 16 parts by weight of oxygen, in the second 32, in the third 48, in the fourth 64, in the fifth 80 parts of oxygen. Now you see these numbers follow the order of the natural numbers one, two, three, four, five, the quantity of nitrogen in each case being the same, namely, 28 parts by weight. Moreover we know of no substance which contains a less quantity of oxygen than 16 parts, or which contains anything between 16 and 32, or between any of the other quantities I have named. But not only do these numbers obtain when oxygen and nitrogen combine; they hold good also whenever and wherever oxygen is united to another element. Take any body you like which contains oxygen, and you will invariably find upon careful analysis that the proportion of oxygen present is either 16 parts by weight, or some multiple of 16. Take again sulphur and iron. Fifty-six parts of iron combine with thirty-two parts of sulphur to form a substance known to chemists as sulphide of iron. Fifty-six parts of iron again combine with seventy-one parts of chlorine, and with the same seventy-one parts of chlorine thirty-two parts of sulphur combine. And in just the same way we might go through the combinations of every known element with every other. In every case we should find that this same law of multiple proportions holds perfectly good.

The discovery of this wonderful law represents an immense amount of patient toil upon the part of numerous investigators; but something more than mere industry was necessary for the interpretation of these interesting facts, and that is the peculiar insight into the mysteries of Nature, that keen yet strictly logical imagination which great scientific discoverers must possess, and this was supplied in the instance we are now considering by John Dalton. These constantly recurring weights, he argued, must represent definite masses of matter; let us call them *atoms*. When we get a compound having sixteen parts of oxygen, we are dealing with a single atom of that gas in the ultimate particle of the compound, and when we find thirty-two parts there must be two atoms of oxygen present, and so on. Upon this he founded his Atomic Theory, and I will now state it fully. "All matter consists of minute indivisible ultimate particles called atoms, which are of the same size but of different weights. By mutual attraction these particles unite to form compounds; the atoms of the same element are, however, all of the same weight." See how beautifully simple this theory is, and how easily we can explain by its means the facts which I referred to just now!

Take the case of nitrogen and its compounds with oxygen. It is obvious that the smallest particle of the simplest compound on the list must contain only one atom of oxygen. Now if we want to combine more oxygen with the nitrogen, we must add one or more atoms to it, for the atoms being indivisible we cannot add a part of an atom, and so we get the higher oxides of nitrogen to contain respectively two, three, four, and five atoms of oxygen. Just the same holds good in every case. Assuming the combining weight to represent the weight of the atom of an element, it follows that wherever that particular element is present, it must exist in the proportion of its atomic weight, or of some simple multiple of that weight.

But before we proceed farther, I must explain to you exactly what these atomic weights are, and give you a general idea of how they have been ascertained. I have to-night mentioned some of these weights, and in books on chemistry you find a list of the so-called elements, with a number opposite each, which represents its atomic weight. Now, of course, it is quite impossible to weigh an atom directly, because if they exist at all they must be extremely minute, and are far beyond the power of our best microscopes. But although we cannot directly weigh an atom, we can determine the ratio which the weight of the atoms of all the elements bears to that of the atoms of some other substance selected as a standard; and this is just what the so-called atomic weights express. As you are, of course, aware we make use of a similar system of weights for many other purposes. We speak of the *specific gravity* of a substance, meaning thereby, not its absolute weight, but its weight as compared with an equal bulk of water. When, for instance, we say that the specific gravity of gold is nineteen, we mean that a cubic inch or a cubic foot of that metal weighs nineteen times as much as a cubic inch or a cubic foot of distilled water. Just in the same way as we select water as the standard with which the specific gravities of most other substances are compared, Dalton selected hydrogen, the lightest substance known, as the standard with which to compare the atomic weights of all the other elements. Hydrogen, in accordance with his system, is said to have an atomic weight of one, and when we say that nitrogen has an atomic weight of fourteen, and oxygen an atomic weight of sixteen, we mean that the weight of the atom of nitrogen is fourteen, and that of the oxygen atom sixteen times the weight of the atom of hydrogen. So you see the atomic weights are not absolute but comparative. I may tell you that the numbers assigned by Dalton to the elements were different in most cases from those which we now employ. This arises from the fact that Dalton worked with very imperfect apparatus, and his results have been subsequently corrected.

Nevertheless Dalton's method was correct, and it is to him that we primarily owe the idea of submitting chemical phenomena to the test of the balance.

But now you understand what the numbers which we call atomic weights signify, you will like to know how they have been ascertained. But before I can do this I must trespass upon your patience for a few minutes, while I endeavour to make clear to you three important chemical laws or general statements.

The first of these is known as the law of Avogadro, from the name of the Italian physicist who first enunciated it. It runs thus:—"Equal volumes of all substances, when in the state of gas, and under like conditions, contain the same number of molecules." Here, as you see, we encounter a new term "molecule," which you will allow me to explain. The term molecule signifies "a little mass," and it must not be confounded, as it very often is, with the term "atom." I can perhaps give you a clear idea of it by using an illustration. Suppose I have a block of salt, and that I proceed to divide it up into small particles, and that I then continuously subdivide these particles into smaller and smaller pieces, I shall eventually obtain a particle which will be too small for further division. But suppose in imagination I continue the subdivision of that smallest particle, I think you will see that at last I shall come to a point where, even in imagination, I must stop. Now that small particle which in imagination I should have obtained would be a molecule of salt, and it would have, in spite of its extremely minute size, all the distinctive properties of salt, just as much as the large block from which it is derived. You will now perhaps understand the definition of a molecule which is usually given:—"A molecule is the smallest particle of a substance in which all its properties inhere." According to modern theory, all matter is made up of such molecules which are in constant motion among themselves.

But although we cannot divide a molecule by merely physical means, we *can* do so by the aid of a chemical experiment. By appropriate methods the chemist can break up the molecule of salt into two substances—sodium, a metal, and chlorine, a gas. But now he is dealing not with *molecules* but with *atoms*, so you see that atoms are the constituent parts of molecules, and molecules are the smallest particles of a substance which can be obtained without breaking the molecules up into atoms. Now our law says that every gas has under like conditions the same number of molecules in the same volume, no matter what may be the nature of the gas. That is to say, if we had a quart of oxygen, a quart of carbonic acid gas, and a quart of hydrogen, all at the same temperature and pressure, they would all contain the same number of molecules. Our second law presents no difficulty, as in untechnical language it simply amounts to this. If we double the pressure of a given volume of a gas we shall halve the volume, if we halve the pressure we shall double the volume. Suppose, for instance, we have a quart of gas under a pressure of fifteen pounds, if we make the pressure thirty pounds we shall compress the gas to a pint, but if we take half the pressure off, so as to leave only seven and a-half pounds, the gas will expand to two quarts.

Our third law requires some explanation. We all know what ordinary temperature is. It is quite an arbitrary condition. When we say that the temperature of a body is 70°, we mean that if a thermometer is applied to it the mercury will rise to a certain point marked on the scale 70°. But this gives us no information as to how much heat there is in the body. If we take two different substances, let us say water and spirits of wine, both of which, when tested by the thermometer, show a temperature of 70°, and if we apply heat to them until they both show a temperature of 80°, we shall find that much more heat will have to be applied to the water than to the spirits of wine. Just the same is true of every other substance; the temperature which they exhibit bears no relation whatever to the amount of heat which they contain. But scientific men have constructed a scale of temperature which does bear a relation to the actual heat contained by a body, and which is therefore termed absolute. Allow me to suppose that we have here a long cylindrical tube, closed at the bottom and open at the top, and we will suppose further, that the air in the tube is closed on the top by a moveable piston, the weight of which we will disregard, as also its friction against the tube. If we apply heat, the temperature rising will cause the air to expand, while, if the temperature falls, the air will shrink, the piston rising and falling in obedience to these movements of the air. Suppose the air to be cooled down to the freezing point, and let us note the point of our tube to which the piston falls; this will of course be 32°. Now heat the air until it is of the temperature of boiling water, and again mark the point to which the piston rises; this will of course be 212°. Lastly, let us divide the part of the tube between these two points into 180°, as in our ordinary thermometers, and let us continue the divisions on both sides to the top and the bottom of the tube. We shall find that below 32° we can make just 491 such divisions; so that our lowest graduation will be 459° below the freezing point of water; now, if we call the bottom of the tube zero, instead of 32° below freezing point, we shall have something like an absolute scale of temperature, one in which we *can* say that the temperature at 500° is twice as great as the temperature at 250°. Moreover, as you have seen on this scale the volume of the gas is directly proportional to the temperature; that is to say, the volume of a given mass of gas at 500° will be twice as great as the volume of the same mass at 250°. This is just what our law states, and it only remains for me to remind you that we can always convert degrees of our ordinary thermometer into degrees of the absolute scale by adding 459°. For instance, we have a quart of gas at 5° Fahrenheit, and we want to know how much it would measure at 469° Fahrenheit. By adding 459 to each of these numbers we get 464 and 928, the latter of which is just double the former; and so the answer is two quarts.

Of these three laws, the last two are altogether independent of any theory—they are merely the summation of universal experience. The so-called atoms and molecules may be entire myths, mere figments of the imagination, the atomic theory may be a delusion and a snare, but these laws would be unaffected, and, as far as we know, will remain true until the end of time.

The first law is a theoretical assumption, but it is nevertheless supported by evidence which may fairly be termed "overwhelming." Into that evidence I have no time to enter fully this evening, but I may assure you that there can be little, if any, doubt concerning it. Moreover, if we do but assume the truth of this law of Avogadro, the two other laws which I have mentioned are the necessary consequences of it. Take Boyle's law for instance. A mass of gas enclosed in a vessel, whether that vessel be a glass globe, a balloon, or a steam boiler, pictures itself to the mind of the scientist as a collection of minute particles in constant motion, hurrying through the vessel in all directions, and constantly pounding away at its sides; and this pounding, this bombardment of the sides of the vessel by the molecules, is what we know as "pressure." Squeeze the same quantity of gas into half the space and you obviously have in that space twice as many molecules as before—twice as many tiny missiles hurling themselves against the sides of the vessel, and therefore double the pressure. Look again at the law of Charles. Scientists believe that the motion of the molecules of a body is heat, and that if you could abstract all the heat from a substance you would destroy the motion of its molecules. Well, assuming that in a given volume of every gas you have the same number of molecules, you would expect that all gases would expand an equal amount when subjected to an equal increase of temperature.

Moreover, there is another striking proof of the law of Avogadro supplied by the science of heat. As I have already intimated, different substances require different amounts of heat to raise their temperature an equal number of degrees. Well, if we take a number of substances and compare the quantities of heat required to raise each of them one degree in temperature, we find that those quantities are in exactly inverse proportion to their atomic weights.

But it is now time I pointed out to you how by the application of these laws the atomic weights of the various elements have been ascertained. Where the elements exist in a state of gas at ordinary temperatures it is of course easy to take a measured quantity of the gas and compare it with an equal volume of hydrogen at the same temperature and pressure. Take oxygen for instance. A quart of oxygen weighs sixteen times as much as a quart of hydrogen, and as, by Avogadro's law, there must be the same number of molecules, and therefore what is true of the mass must also be true of the molecule, and the molecular weight must be sixteen also.

But then other elements are solid or liquid at ordinary temperatures, and can only be converted into gas at high temperatures. Well, here we have no real difficulty, the process is only a little more complicated. Let a given volume of the gas be weighed at a known temperature and pressure. By the laws of Boyle and of Charles we are able to calculate by a simple rule-of-three sum the weight of the standard volume of hydrogen under the same conditions, and again the law of Avogadro enables us to fix the atomic weight. Lastly, in those cases where we cannot volatilise a substance at any temperature we are enabled to infer its atomic weight from its chemical constitution and relations.

It is therefore, as you see, perfectly possible to weigh the molecules and atoms of matter although they are so extremely minute, and they are to the scientific man definite masses of matter having a real existence. That this is the case you will readily believe when I tell you that that great mathematician Sir William Thompson has calculated the number of molecules which a litre of hydrogen contains at the freezing point of water, and under the ordinary pressure of the atmosphere. The number he assigns is expressed by twenty-three tens multiplied together, or, as the mathematician would say, by ten raised to the twenty-third power. The same mathematician has also given us a capital illustration of what this means. He says that if we could take a drop of water the size of a pea and magnify it to the size of the earth we should see the molecules of which it is composed, and that they would appear to be in size something larger than fine shot, but not so large as cricket balls.

But I fear I have trespassed on your patience too long, and we must leave this interesting subject of atoms and molecules. I have I hope said enough to convince you that the atomic theory of chemistry is not a mere hypothesis, but has taken rank as an established scientific theory. And just as in the domain of chemistry we find that the wonderful transformations which matter undergoes are the result of energy working in obedience to natural laws, so to whatever part of nature's kingdom we turn our attention we perceive that the wonders which she works are not the results of mere blind chance, that still less are they caused by the random dictates of some merely capricious power, but that they are all the offspring of inexorable, but benevolent laws.

VI.

ICE, AND THE ICE AGE.

WHEN I last had the pleasure of addressing my audience here, I endeavoured to make clear to you certain very important and interesting facts concerning the structure, origin, and effects of volcanoes, earthquakes, and one or two natural phenomena connected with them, such as boiling springs, which undoubtedly owe their origin to the all-potent power of heat. On this occasion I have to talk to you on the subject of ice, and the ice age; one which may appear to you to be the very antipodes of that which I dwelt upon previously; but I hope to show, before my lecture is concluded, that the subject we have now to consider is, after all, only another phase of the same action of heat, and that without heat we could have no ice and no snow, no glaciers, icebergs, or any other of the icy things about which I have to speak. You may probably know that the two most potent agents which have been through all ages working upon this earth since it has been a cool globe, have been the two great agents of heat and water; and I think I mentioned to you before in passing one or two facts elucidating the action of water upon the land in eating it away.

I want to say a good many things to-night about water; and first of all, it is better to mention the principal forms in which we find water existing on this globe. The three forms which, of course, will naturally suggest themselves to you will be, first, water as a fluid; secondly, perhaps water as ice; and next, water as steam. Then, of course, we have water also in the shape of dew, or hail, rain, and snow; and the different characteristics of these I want to point out to you, in order that we may thoroughly understand the nature of that special form of water of which we have to talk—viz., ice and its action in moulding and modelling this earth of ours into its present wonderful and beautiful form.

You of course all know the difference between water and steam. You know, of course, if you take a block of ice and submit it to the action of heat, it very soon begins to melt, and it is converted into water, and further, that if you continue to apply heat to it, you eventually bring it into the condition called boiling, when it passes off as steam. We all know that the difference in these three stages is merely a difference of heat, but I dare say you do not all know the full extent of that difference of heat.

Now supposing we were to take a saucepan full of ice and were to put it on a fire, placing in the saucepan a thermometer. On the thermometer we have a point known as the freezing point of water, which point is 32°. If you put your thermometer into the melting ice, you will find that the mercury in the instrument will sink until it gets to 32°, and there it will stop, and moreover, stop until every particle of ice in that saucepan is entirely converted into water; while there is the tiniest portion of ice there, so long will the thermometer stand at 32 regardless of the fact that you are constantly applying to the water quantities of heat. When you get your ice all converted into water, the thermometer will rise, and continue to do so, supposing of course heat is still applied to it, until it gets to the point which we call the boiling point of water, which is 212°, and at that height it will remain until all the water is converted into steam.

It is very obvious that if we had a large saucepan of ice, a very large amount of heat would be necessary to convert that ice into water. Our thermometer does not tell us anything about that heat, as to what has become of it. Where has it gone? Well, it has become, as we say, *latent* or hidden. This term is not a very happy one with regard to our present theory of heat, but it was one which was first employed when heat was thought to be a substance, and was supposed to be hidden in the particles of water, but the present belief is that the heat which thus disappears is employed in tearing apart the molecules, or particles of which the water is composed, and converting them into a liquid condition.

You will then understand that when a quantity of ice is turned into water, a very large amount of heat disappears, giving us no evidence whatever, as regards its registration by the thermometer, as to what has become of it, and which we call latent heat. I may tell you that to convert a pound of ice into a pound of water without raising its temperature, 147 units of heat required to be consumed, which process does not affect the thermometer. I told you that when you had got your water to boiling point, the thermometer would still stand at 212°, so long as any particle of water remained. When a pound of water is converted into a pound of steam without any change of temperature, we find that 967 units of heat are required, which then disappear and become latent; so we are in the habit of speaking of the latent heat of ice as being 147, and the latent heat of water as 967. These facts we shall see better presently, but this is a sufficient explanation of them for the present.

The forms of water which I have specially to speak about are the forms known as ice and snow. We have, of course, during the last few months, had a considerable experience, for our climate, of both; therefore, you know very well what these substances are like in our streets; but, of course, I need only remind you that if we were to live in some European countries, such as Switzerland, in the midst of summer, we should find that the tops of the mountains are all covered with snow and ice even in the blazing sun. For instance, in Switzerland all the mountains which are above 8500 feet in height (and there are a great many of them, the tallest being something like 16,000 feet high) are constantly covered with ice and snow.

First of all, How did the ice get there? Secondly, the question is, Does it stop there? And the third is, If it doesn't stop there, where does it go to? Don't think I am going to preach a sermon, because I take these three heads in order to see if we can find out the answer to these questions. First of all, as to the appearance of this ice, we will show you a picture which gives a view of one of these mountains in the Alps, the topmost peaks of which are covered with everlasting ice and snow. The first question is, How did it get there? Well, this will take us a little time to answer; and I must ask you to allow me to refer you to what takes place in our streets after a shower of rain, of which we have had so many lately.

Drury-lane, though it is by no means a favourable spot for observations upon the results which follow a shower, that is to say, the natural results—of course, the artificial results, created partly by the great amount of traffic and partly by the neglect of the vestry, are a considerable amount of mud and discomfort. These we do not want to say much about; but in a comparatively clean part of the town, the City, for instance, where they *do* keep things a little bit near the mark, after a shower the rain begins to dry up—the pavement and roads get quite dry. Well, now, where does the water go to? and the answer to this is one of the most important facts which I want to impress upon you.

This water goes into the atmosphere, which takes it up in an invisible form, which is not water, nor yet steam, but something between the two, which we call vapour. Here I have to remind you of latent heat, inasmuch as when water is converted into vapour a considerable amount of heat is employed in the process. If evaporation thus goes on from the wet pavement, surely it must go on much more rapidly and regularly from the surfaces of rivers, lakes, and seas; and so it does.

The sun, you know, is constantly drawing up, or as we say, evaporating, water from the surfaces of all our seas, lakes, rivers, springs, ponds, and every other accumulation of water on the earth, and even from the surface of the everlasting snows on the tops of the mountains evaporation goes on; water is taken up even from the snow. A quantity of vapour goes into the atmosphere, as I said, and becomes visible, here below, as a fog, but up above we see it in the form of clouds.

As we look at the clouds, especially when we see them a little way out of town on a summer's day—those beautiful, white billowy clouds, floating along the blue sky, how often have you wondered what those fleecy masses were really made up of! If you were to go into Switzerland, or in our own country, into Wales, you would easily be able to find out. Not many months ago, I was at the top of a very lofty mountain in Wales, Cadr Idris, and as we got near the top we went right into a cloud. I knew what a cloud was before, but I had never before practically experienced being in one. When we got into it, we found it to be exactly the same as a very damp fog down below, not a thick London fog, but a sort of Scotch mist, and the only difference between it and a misty fog was that, whereas the misty fog generally lies on the surface of the earth, this was more than 3000 feet above it.

I may tell you that the feeling there was an extremely weird one. We had got into the middle of this fog, not without some little danger, and were on the topmost peak of this mountain, Cadr Idris, which is only the Welsh way of saying the Chair of Idris, as it was supposed to be the resort of a great giant, who used to keep a sort of observatory there, where, weather permitting, he used to observe the motions of the sun, moon, and stars. We found our way to a cairn, or heap of stones, right at the top of the mountain, supposed to be the ancient giant's chair, and there we sat shut out from the world entirely, surrounded by this fog, and not able to see more than a foot or two in front of us, 3000 feet above the level of the sea.

Thus we may take it that what we look at in the clouds is nothing more or less than vapour, water in a form between that of pure water and steam, by some force, which we do not exactly know all about at present, suspended in the atmosphere, reflecting light, which gives us those beautiful white masses with their different graceful shapes.

I may tell you of another very interesting thing one meets with in these mountainous parts, which is a sort of thing between a mist and a cloud. In these places we very often seen on the top of a mountain a cloud looking exactly like a banner—"cloud banners" they are called. I went up into one of these cloud banners, and experienced nothing but a driving mist, with a violent wind blowing, carrying this cloud really with considerable velocity away from the mountain. As soon as any air reached the mountain, charged with an amount of vapour, it got partly condensed—the moisture wrung out of it—and so we had this cloud, the form of which was perfectly stationary, although the materials which composed it were constantly in motion.

To return to *terra firma.* Knowing what a mist is, what a genuine fog is, and what a cloud is; there is one other form of mist I want to speak about—and that is, dew. You know, of course, that very often in the night a quantity of dew is deposited, and that if you went out in the early morning you would find all the wood and the foliage of the plants in the garden covered with moisture. That dew owes its origin to just the same conditions of things as snow and the like, of which I have to speak.

I daresay you may know that, if you have a particularly sweet tooth, and put a lot of sugar in your tea, it will not all dissolve. At any rate you can try the experiment with either sugar or salt. If you put either one or the other into water you will find you may go on adding the salt or sugar up to a certain point, and then you can get no more to dissolve. If, however, you warm the water, you can get more of the material to dissolve than you can in cold water; and if you go on warming the water you will find, within certain limits that the more you warm it, the more salt or sugar will the water dissolve. But at every temperature you will find there is a limit beyond which the liquid will not take up any more material; and when that limit is reached chemists say we have a *saturated* solution—viz., a solution which will not hold any more of the material dissolved.

Just so with the air and this vapour. At a given temperature the air can just take up a certain amount of moisture, but if the air be cooled, of course its capacity for holding moisture is decreased, because, just as in the case of our mixture, the more heated the air, the more water will it hold. I think you can see this in the case of dew. If we have a very hot day, the air, of course, takes up a very large quantity of moisture. After the sun has set, the air and the earth begin to get cold; but the earth gets cold more quickly than the air, consequently the earth chills the air which is immediately above it, and thereby reduces its power to hold the water in solution; therefore it is deposited upon the earth in the shape of dew, and if the temperature only sink low enough—viz., to 32°, then the dew is precipitated or thrown down upon the earth as hoar-frost. That shows us how the air may be made to give up its moisture.

Moreover, I may remind you that some substances will become covered with dew much quicker than others. For instance, the gardener covers his plants up with matting, and you may have noticed that it and the gravel paths have scarcely any dew or hoar-frost upon them, although all the leaves and wooden edging to the flower-beds is covered with it. The solution of this simple problem is just this; the matting parts with its heat very slowly, consequently, you see it does not get cool so quickly, and does not chill the air which is upon it. It is just the same with the gravel, but the wood and plants get colder quicker and chill the air above them, and so get covered with dew.

That is a very beautiful explanation of what takes place here upon the surface. Now let us take ourselves to the clouds. A cloud, you know, is a quantity of this vapour, which is held in suspension in the air, and rendered visible to us by the reflection of the sun-light. Supposing such a cloud meets with a cold current of air, or supposing, which is more common, it comes against the side of a mountain, two things happen. Of course the cloud cannot get through the mountain, so it has to do like we have to do, it has to go over the top. It goes up to the top of the mountain and then over, and then, the mountain being cold, the cloud gets chilled. Moreover, for a reason I shall have presently to tell you, the higher we get from the earth the colder is the air; therefore the cloud, in being made to go up higher from the earth, gets into the colder regions, gets chilled on the way, and consequently, its power to hold the water it contains in suspension is reduced, and down comes a shower of rain, or, if it be cold enough, a shower of snow.

The influence of mountain chains in the regulation of the amount of rain in any given neighbourhood is something astonishing. At Seathwaite, in Cumberland, on the windward side of the mountain range, there fell 182 inches of rain in a year, while the average on the other or leeward side was just about 19 inches; so you will find, taking it as a general rule, that you will get an enormous quantity of rain on the windward side, where the clouds lose their moisture, for when it gets to the other side it is comparatively destitute of it, and we have, therefore, very much less rain.

This is, at least, a general answer to the question, How does the snow get to the top of a mountain? for you see, given the existence of water upon the earth, we have seen how constantly that water by evaporation is being taken up into the clouds, and the clouds, getting chilled, down it comes, either as rain or snow. In the upper regions of the atmosphere, as on the tops of lofty mountains, it always descends as snow; and in this way we see how it is that the snow is found on the tops of mountains. I want to show you now that it could not have got there without heat. I told you just now that whenever ice is converted into a state of water a quantity of heat is required, which is rendered latent, or hidden, in the process. Well, now, if it were not for the heat of the sun not a single drop could be lifted, not a single particle of snow could fall upon the mountain tops or anywhere else; so you see heat, the very same agent which works volcanoes, which tears up the surface of the earth, which gives us boiling springs, which slowly upheaves the land in one place and causes it slowly to subside in the other, works in the tiniest raindrop and in the beautiful crystals, which we call stars of snow.

The next question is, Does the snow remain on the mountain tops? Our next picture will give us a reminder, in a view of one of these ice-clad mountains, in which that question is answered in the negative. You have all heard of avalanches. An avalanche is simply an enormous mass of snow precipitated from the summit of a lofty mountain, coming down with fearful force into the valley below, overwhelming villages and people, and everything else that comes in its way. In the case of the avalanche we have the sudden fall of a large amount of the snow which gathers at the top of the mountain, and that is simply due to that law which we know as the law of gravitation ; it falls from the top of the mountain for just the same reason as a stone falls off the top of a table. A great deal of snow accumulates year after year, which of course presses upon the snow which is already there, and consequently there is a great pressure, and eventually large masses fall off.

We have seen how snow accumulates on the mountain tops, and, as in the case of the mountains in Switzerland, all over the height of 8500 feet are constantly covered with snow. As the snow falls and accumulates, the pressure, of course, gradually becomes enormous, and, as it has been found by experiment that if you take a quantity of snow and press it very much, you can convert it into a beautiful blue ice, just in the same way the snow which accumulates on the top of the mountains is by constant pressure month after month, year after year, converted into ice, and so we find that we have a small layer of snow, and enormous masses of ice, many thousand feet in thickness sometimes.

In the next view we have a representation of what is known as an iceriver, or *glacier*, from a French word signifying ice. There coming down the mountain side we have an immense mass of ice. I say coming down, advisedly, for we know that this mass of ice is actually moving along. The glacier is an immense mass of solid snow, converted by consolidation into ice, which is gradually moving down the mountain side.

For a long time it was a question as to whether these glaciers really moved; but that question was set at rest many years ago by some experiments, which consisted in putting a number of stakes across the glacier, making accurate marks as to the parts where they were placed, and watching them week after week to see if they moved. In this way it was soon found that these glaciers really were moving on at a somewhat considerable pace ; moveover, several other facts tended to confirm this opinion, as we shall presently have to show.

In our next picture we have a view of a tremendous fissure in one of these mountains, down which three guides fell some years age. Their bodies were not found for some time, and then they were discovered more then fifty miles lower down than the spot where they fell, showing, of course, that the ice must have carried them along.

Upon all these glaciers are always found quantities of rubbish, such as blocks of rock, smaller masses of the same material and powdered rock, which have fallen upon the glacier owing to the action of the weather in splitting up the rocks. One result of frost, in consequence of the expansion of ice, is to split up the rocks, and very often huge masses are broken off in this manner from the mountains, and fall upon the glaciers. In addition to this, as the glacier passes along it grinds the surface of the rocks, and in this way also a great deal of rubbish is accumulated.

These different masses of rock found in the glaciers are what are called *moraines*, or heaps, and those by the side are, for distinction's sake, called *lateral moraines.* If we were to walk down this glacier, of which we have a view as far as it winds its way, we should find, of course, as we came down the mountain side that it got warmer, and eventually we should reach the end of the glacier where it begins to melt, and when this is the case it often gives rise to a river. The Rhone rises from a large glacier in the Alps.

Just at the end of the glacier is an enormous mass of this rubbish, very similar to these lateral or side *moraines*, and this heap of rubbish is what is known as a *terminal moraine.* You will see presently that I shall have a reason for mentioning these facts.

Besides these heaps, we also find that there are a large number of clefts and fissures in these glaciers, some of them of very enormous extent. We have some represented in the view now before us. These holes in the glaciers are known as *crevasses*, and they are, as I just now said, very numerous, and some of them are two or three thousand feet deep.

You will easily understand that into these crevasses—these holes in the glacier—a large quantity of rubbish will be constantly falling; moreover, this rubbish, getting to the bottom of the glacier, and consisting of large and small masses of rock, will exert, as the glacier moves along, a very considerable grinding and polishing power. You know how emery powder polishes steel; well, just imagine an enormous river of ice, perhaps a thousand feet or more in thickness, carrying with it these masses of rock, and then imagine what an enormous polishing power this must have upon the rocks it passes over; consequently we find, when the glaciers melt, as certain parts will, in the summer, beneath what is known as the snow line, lower down than 8500 feet, we find that the rocks are very much scratched and polished. This is the characteristic of the rocks which have been in any way acted upon by these glaciers; the scratching being always in the direction in which the glacier has been travelling. Moreover, those stones which are piled up under the glacier, and which form the terminal *moraines*, have been rubbing the rock over which the glacier has passed, and in scratching the rocks beneath, have themselves been similarly treated; consequently they also are very much striped and polished; and if you take up any of those pieces of rock which are to be found in these *moraines*, you will find they are always striped and polished.

We will now show you another view, which will suggest one or two other features in connection with these glaciers. Besides these *moraines* and *crevasses* we find that there exist on the glaciers and in glacial regions a number of very curiously piled-up striped rocks. We have one here 800 feet above the sea level, and if you have a rather strong imagination, and look at it knowing what you have to expect, you may perhaps see that it looks something like a man. Consequently they have called this pile of rocks, which is about 50 feet high, Peter Botte. The rocks have been placed here by the action of the glaciers, and so Peter Botte has been put in his present position. I will try and explain how this is.

I do not know if you ever heard of an experiment which Benjamin Franklin once performed; if you have not, it will not take many minutes to tell you. He wanted to know what was the effect of different kinds of cloth in keeping us warm, so he cut up a number of different coloured cloths and placed them one very snowy day upon the snow, and watched to see, when the sun came out and the snow had ceased, how far these pieces would sink into the snow. The darker pieces sank in the most, the reason for which was that they absorbed the heat and conducted it to the snow much better than the brighter coloured ones; consequently the snow melted more rapidly under them than under the brighter pieces. This explains why we wear dark clothes in winter, when we want something that will keep in all the heat and not allow it to go out. As our bodies are constantly generating heat, we wear dark clothes as much to keep in the warmth as to keep out the cold. On the other hand, in the summer we want to get rid of some of this heat, and then we use lighter clothing, which reflects the heat of the sun, radiating the heat instead of absorbing it.

The rocks of which we were speaking are placed in their position in much the same way. The ice, as it moves along, gets covered with rubbish; this keeps it warm, consequently some of it melts, and these rocks are very frequently left behind. In addition to the rubbish which is found upon glaciers, we frequently find huge blocks, which are carried a long way by the glacier, and as the latter melts, are sometimes piled up in a very curious fashion. In our picture we have an example of a rock perched on the top of a very curious pillar. It could not have got there by any other action than by the action of glaciers; moreover, the glaciers at one time were very much greater and more important than they are at present. In the view presented we have instances of *crevasses* and also of these "perched blocks," as they are called, resulting from the blocks being carried along by the glacier and placed subsequently upon the top of other rocks when the glacier melted.

It sometimes happens that two glaciers do the same as two streams do—that is to say, they come to a point and unite. I think you will see that if this were to take place, that the two inside *moraines* would unite to form a mass in the middle, and this is how medial *moraines* are formed. Besides all these things which I have mentioned, there are also such phenomena as glacial tables, of which more will be said presently.

The time has now come when I may say something as to how glaciers move. Among others, Professor Tyndall a few years ago investigated very closely indeed this very glacier, in Switzerland, the view of which is before us. By putting a number of stakes across, and watching them, he found that the stakes moved along at a certain rate, but that those outside did not move at the same rate as those in the middle, and that those in the middle moved the fastest. Before his time it had been ascertained that a glacier moves just in the same way as a river—viz., that the swiftest part of the current is in the middle. It is also the case with a river that the lower parts, those near the bottom, move more slowly than those above. Tyndall, by his experiments, found that, moreover, like a river, with the glacier the swiftest point is always on the outside of a curve or on the convex part of it. Thus we have a knowledge of these important facts—that a glacier moves in the same manner as does a river, that the sides move more slowly than the middle portions, that the bottom moves more slowly than the top, and that when an ice river winds, the point which moves fastest is the convex part of the curve, and that it shifts with the windings of the valley through which it flows.

I may tell you that for a long while it was a puzzle to men of science to know how it was that ice, being, as you know, a solid, was able to move along like a liquid. That puzzle was one that caused a great deal of research among a good many learned men, until eventually it was solved by the great Faraday. Some people thought ice was something like treacle, and that it might move along like that substance; but that would not answer, and a great many other theories were started. In order that we may clearly understand the matter, let us thoroughly consider the extent of the difficulties before us. We have an immense mass of solid material, and in the case of a glacier moving down the valley you can easily conceive of its motion if the valley were perfectly straight, and of the same width all along. But supposing, as, of course, is really the case, in some places the valley is very much wider than in others, sometimes the ice stream would be too broad to pass through it, while in other places it would be only about a fourth as broad as the valley. Suppose, too, as is also the case, that the ice river has constantly to wind about, turning corners, you see at once that you cannot conceive, upon the ordinary principles of the movements of solids, how the mass can accommodate itself to all the widenings and narrowings of the road it has to travel.

These are the difficulties which present themselves, but they have been solved. If we were to take two pieces of ice, and, even in front of the fire, put them together, they would fasten one to the other; and if you placed a number of small pieces of ice in a basin, you would find that these small pieces, being in contact, would stick together and form an irregular mass; and however you may break a block of ice it will always freeze together again. This property of ice Faraday called *regelation*, which simply means, freezing together again. Now if the ice in the glacier does this you can easily see how it is that it can accommodate itself to the valley in the path that it has to travel through. When it is too narrow for it it "smashes up" and gets piled up higher, and so passes through and freezes together again; when the valley is too broad it spreads out. This has been ascertained to be the reason why we find this enormous mass of ice moving along like an ordinary river, by virtue of the property which the ice possesses of freezing together again. So this difficulty has been got over.

I have already spoken to you of those blocks of rock which are carried along by the glaciers; in our next view we shall have an example of one of these rocks which have been thus transported, and in order that a comparison may be made as to their height the figure of a man has been painted close to it. The block of rock represented exists in a country where there are no glaciers, and differs totally from all the rocks anywhere near it. It could not very well have got there without being carried, it did not grow there, and it is evidently far too big for any human agency to have lifted. These erratic blocks are the most important evidence which we have of the existence in past times of glaciers where they do not exist now.

Our next view gives us a picture of another thing connected with glacial action—viz., a glacial table. We find very often on the glaciers an immense mass of rock, piled up on the top of a quantity of ice. How does this happen? Here we have a view of one of these glacial tables in Switzerland, in which the striping which I have been speaking of is plainly visible. How is it that on the glacier there should be this immense mass of rock, supported by this column of ice? To answer this question I must take you back to Franklin and his piece of cloth. We have seen how these blocks of rock fall on the glacier, and so we can easily see that when the sun shines all the ice under that block would be in the shade. I told you that the air is very much colder as you get farther away from the earth than it is on the surface. The reason of this is that the sun, which gives us heat as well as light, does not warm at all the air through which its heat passes; the only way in which the air gets warm is by getting heated by reflection from the earth; consequently, when we go above the earth's surface into the regions where the air is out of the range of this reflection, it is fearfully cold in the shade. Thus you can very easily imagine that the ice beginning to melt would do so much faster in the sun than in the shade, and that the ice underneath the rock would melt very slowly indeed; consequently the rock was left behind, and so we have this glacial table. These tables do not stand quite level; they point north and south, but the south end always bends downwards. This is the case by reason of the sun shining in the south, which causes the south side to get warmed more than the north, and therefore, the ice to melt quicker on that side. These glacial tables eventually slide off.

We have now some other features to consider, which will take us to another part of the world. In the case of the Alps, in Switzerland, we find that, of course, the glaciers, when they come down the sides of the mountains, gradually melt and disappear. But if we go into Arctic regions, we come to a region in which ice always exists, and in which the glaciers, instead of passing down the mountains and getting melted, go right down into the sea; consequently we have in the sea huge masses of ice broken off from the glaciers, and which we call icebergs.

By-the-bye, we see that ice does not sink. A solid is usually heavier in bulk than the same substance in a liquid condition. Very fortunate for us is it that ice is an exception to this almost universal law. You know that as a general rule heat expands bodies and cold contracts them. However, that is not, as the Irish schoolboy thought, the reason why the days are short in winter and longer in summer; nevertheless, it is a natural law, almost without exception, that heat expands bodies and cold contracts them. How does water act? I well tell you. Supposing you had a large tub of water, at, say 40°, and you begin to cool that water by the application of ice, you would find, like everything else, it would begin to contract, getting smaller in quantity until it got to about 7° above freezing point; then you would find that the water will get no smaller in quantity, and as it cooled from 39° to 32°, it would begin to expand, contrary to almost everything else in nature. What is the importance of this? A cubic foot of ice naturally weighs less than a cubic foot of water; consequently the former floats on the top of the water, and happily for us, as it preserves the water against further frost; for, supposing the water, like everything else, went on contracting, all our water, every river, lake, pond, and even some of our seas, would soon become nothing else than huge basins of ice, which all the heat of succeeding summers could not possibly melt. You see, by this wonderful provision, how the ice, lighter than the water, floats on top, and protects the water underneath.

We thus see how ice floats upon the water. There are only one or two other materials, such as cast-iron and bismuth, which expand a little as they cool; and in the case of cast iron, provision has to be made accordingly. So enormous is the expansive power of water as it cools into ice that it will burst the strongest gun; by simply filling them with water, which is allowed to freeze, the solid guns will be actually torn open by it; and it is a common lecture-table experiment to fill cast-iron bottles and burst them by freezing the water in them.

Icebergs are nothing else than immense masses of ice broken away from the glaciers, which in these Arctic regions come down right to the sea. As these glaciers push the ice down it breaks it off. Some of them have been noticed several miles long, and from 100 feet to 300 feet in height, and it has been calculated that many of them must weigh about 100,000 tons. On them also we find a quantity of rubbish, and this is occasionally supplemented by huge blocks of rock. In our view we see the glaciers jutting into the sea, and they will soon break off and float away, and we see these magnificent icicles hanging from the tops. As the sun melts the ice from the top it trickles off as water, and directly it has got over the side it gets in the shade, and thus these beautiful icicles are formed.

In our next view we have a picture of an iceberg floating away from the glacier, and bearing along with it a quantity of rubbish and pieces of rock. They gradually float away, until they eventually get melted. Sometimes they have been seen stranded in from 1500 feet to 2000 feet of water, and on one occasion one of them floated to the Island of Newfoundland, and had a fearful effect on the climate. All through the summer time it was so intensely cold that the crops would not grow, which instance shows what an enormous amount of cold these icebergs can produce. The proportion of them which we see above water is only a sixth of the total mass; that follows from the difference in the weight, bulk for bulk, of ice and water. What, then, must happen to the rubbish which these icebergs bear away when they float into a warm region? The blocks of rock, etc., which they carry invariably fall to the bottom of the ocean, and so over the ocean floor must be distributed these blocks, differing totally in character from the material which constitutes the floor of the ocean itself.

Now, putting all these facts together, let us see whether they throw any light upon the past history of our own country. I have told you somewhat of the character of the glaciers, and I wish, if possible, that you may see things with your own eyes, and to judge of them by the aid of your own common sense. In the Alps at the present time we know that glaciers now exist, but they are very small in comparison with those which must have existed in times gone by. How do we know this? In the glacial regions of Switzerland we find immense heaps of rubbish, which consist of stones which have been polished and scratched, ground and striped, just as in the rubbish in the *moraines* in the present day. Moreover, we find that these *moraines* are of enormous extent compared with those which now exist; in one instance a *moraine* encloses a circle of more than sixty miles, and which is three miles across at the top, and 1600 feet high; what, then, must have been the dimensions of the glacier which it enclosed?

When we come to our own country we find that all the way up from the north of the Thames, right up through Wales, Cumberland, and Scotland, we find in the first place a quantity of rocks and stones, which exhibit this grinding and polishing, and we also find, disposed in masses, heaps resembling the *moraines* of the present day. Then again we find that there are masses which obviously owe their existence in their present position to icebergs; for instance, in Scotland we find large masses consisting of gravel, sand, and polished stones, which are undoubtedly the result of ice action. Also, we find in parts of England huge blocks of rock, totally unlike any rock in the neighbourhood, such rocks as I showed you a little while since, and which evidently must have been transported from a very considerable distance, and thus could obviously only have been so transported by ice action. In the mountains of Wales and Cumberland, and generally in Scotland, we find that we can trace the remains of the glaciers right up to their tops; there we find enormous heaps of rubbish precisely corresponding in every respect with the *moraines* which we find in Switzerland in the present day, and on the tops of some of the Welsh mountains—they are nearly 1600 feet high—we find the remains of the shells of marine animals, precisely the same as those found right up in Greenland at the present time. In addition to that, as a result of glacial action, in Switzerland we find that the rocks over which the glaciers have passed are smoothed and rounded; and we find this also in the Scottish and Welsh mountains, which could only have been acted upon in this manner by glacial action.

So we are led to conclude, from these and other phenomena, that at one time the whole north of Europe, the whole of our own country, including Wales and Scotland, from about the mouth of the Thames, was covered by ice, precisely as Greenland is covered at the present day. An immense part of this island is covered with what is called an ice-cap. Thus we find features in our own country, in Scotland, and the whole north of Europe, and the north of America, precisely corresponding—so far as the marks on the rocks go—as the heaps of rubbish and the rocks which have been transported from a distance—as far also as the smoothing and rounding of the rocks, and the perching of huge blocks of rock upon the tops of others quite unlike those we find around, go—to what we see where glacial action is in existence in the present day. Consequently we are led to the conclusion that in ages gone by the whole of this northern hemisphere must have been covered with a huge ice-cap, and it is to that period, whenever it was, that we give the name of the Ice Age.

So far as the animals are concerned which lived in that age, they were undoubtedly few. We do not know a great deal about them, but we know they were such as exist in the present day in Arctic regions. For instance, who would expect a reindeer to be walking through any part of our island? We should think if we saw one that he had escaped from Wombwell's Menagerie; yet, nevertheless, it is perfectly certain that so far as the south of France did reindeer at one time exist; and the remains of other animals, now only found in Arctic regions, have been discovered here.

The next view is of the immense sea of ice which was reached by the last expedition to the North Pole, called the Palæocrystic Sea. This is the road to the North Pole, and if that really is the only road, it is a very bad one, and it does not seem as if we should ever get there, for it is nothing but one mass of hummocks of ice. Just as that sea appears now, so do we believe the larger part of this island appeared in days gone by.

The last view I shall have to show you is a very interesting one. It shows the picture of an immense animal which was found enclosed in the ice in Siberia some years ago. This animal was very much like the elephant, but different in some respects. This mammoth, which is extinct now, was preserved in the ice, much as it is shown in the view, and when the ice was removed the dogs that were with the discoverer began to eat its flesh. This animal undoubtedly lived during the ice period.

In conclusion, I heartily thank you for listening to me, and trust you may carry away with you one lesson, and then you will not have wasted your time in coming here. If you will only open your eyes, if you will only look around you, you will find in any and every natural object, however small, however slight, and however apparently insignificant, some lesson. Nature is always waiting to teach us, and waiting to be questioned, if we will only question her; and if we will only open our eyes and look upon the book which is always spread before us, we shall

> "Find tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything."

VII.

TWO LIFE-HISTORIES.

I SUPPOSE there are none of us here this evening who can have failed to be struck by the vast abundance of life by which we are surrounded. We, who live in the very heart of the most thickly populated city in the world, are naturally most struck by the teeming human life of which we form a part, but when we turn from the contemplation of our own immediate neighbourhood, and when we remember that what we see around us of animal and vegetable life is but a small part of that life, much of which lies beyond our individual ken—that not only is the surface of the earth in all parts of the world covered by animal and vegetable life, even up the mountain slopes, on the very top, and sometimes where eternal snow reigns, being represented there by a small fungus; but that down fathoms deep beneath the ocean, there exists an abundance of life; and when, too, we consider the enormous varieties of life with which the naturalist has to deal, we feel utterly incompetent to form even a small estimate of the enormous amount of life which this earth contains. But I think, when we turn from the contemplation of the abundance of life to its nature—life itself—when we endeavour to find out where the difference lies between the living beings which we see around us, and the different inorganic materials with which they are connected, when we attempt to solve that great unsolvable problem of what life itself really is, then, I think, we must be lost in wonder and astonishment, and feel that the study of living beings, or, as it is called, "Biology" (which simply means the "science of life"), is perhaps the most wonderful and interesting of all the branches of science to which we can turn our attention. I wish to trace out for you this evening, very roughly and briefly, the life-histories of two very common objects, one a vegetable and the other an animal, and I think I shall be able to show you that there is something far more wonderful, even in the tiniest flower and in the humblest animal with which we are acquainted, than perhaps we had ever dreamed before.

First of all, perhaps, I had better just say a few words about the differences between things that live and things that do not live. I suppose you think it is a very easy thing to tell the difference between a man, and, say, a block of stone. Very likely it is, in a certain sense; but then as we get lower down we find we must narrow our definitions very considerably in order to find one which shall exactly include all the properties of living matter and exactly exclude all the properties of inorganic matter. A great many things suggest themselves to us when endeavouring to answer the question. We might say, perhaps, that a living thing grows, whereas a stone does not. That, of course, is true of all living things, but nevertheless it is a task, as I have said, of considerable difficulty to form an exact definition.

There are one or two things, however, which give a decisive answer to this question. I shall mention here two of them, these being the most important. First, all living beings, however simple or however complex, owe their origin to some parent who has gone before, and that just gives me the opportunity of saying a few words about a subject upon which there has been a considerabte amount of dispute. It is called by a tremendously long name—spontaneous generation, which simply means, the springing up of life from mere dead matter, without the precession, or going before, of any living material. You may know, perhaps, that all the ponds which we meet with in various parts of the country constantly teem with life, both animal and vegetable, and, moreover, the most curious thing is that each pond has particular forms of life peculiar to itself. If you compare one pond with another some distance away from it, the life in each is often of a different form. Of course, it is a very easy solution of the problem as to how that life got there, to say—"It came there." The question is, How did it come there? That is a question about which there has been a very great deal of dispute. The opinions of scientific men on this matter have varied from time to time. Sometimes people would think these living things really did come there without any antecedent life. This, however, could not, I think, have been the case—at any rate, I must say, although there are some people who think differently, that there can be no living being, however high or low, which has not originated from some preceding living being. Spontaneous generation, the appearance of living matter from not-living matter, is impossible; therefore, we may take it that every living creature which we find upon this earth has in some way or other to be born, and has, although in some humble way it may be, that which we may in general terms call its parent.

There is another thing to be considered—living beings grow. Under this term we do not include inorganic, or dead matter; for, although this can, under certain circumstances, be made to grow, yet its growth is a very different thing indeed from the growth of an animal or plant. This will be made clear to you by a very pretty experiment easily performed by yourselves if you have the time. Take some boiling water, and put some alum in it, as much as the water will take up. Then put it into a basin, and lay a stick across it, from which should be suspended by a thread a little tiny piece of cinder. Leave it there for a few hours, and then you will find the cinder covered with very beautiful crystals—your dirty piece of cinder has been converted into a beautiful crystalline gem. By properly treating such a crystal you could get it to an enormous size; but you see the growth of this crystal, like that of a heap of sand, is growth by the addition of precisely similar material on the outside. You give a cow grass, and it does not take that grass and make it a part of itself, *as grass*, but it turns it into cow, which cow we occasionally eat as *beef!* This is converted, then, into man, and thus I want you to understand that in all cases where living matter grows, it does so at the expense of something outside, and this something is, as we say, digested. Man, for instance, is not a patchwork of the various articles of food which he takes in; of these he makes man, by digestion and assimilation, and so his growth proceeds. There is, therefore, a great difference between the growth of matter that lives and that which does not; but, as I have many interesting things to talk about, I must leave this subject for the present.

The first of the life-histories which I am going to talk to you about is that of a common scarlet-runner bean. You all know what the seed is like, I suppose. It is a seed which has a depression on one side, which gives it somewhat the appearance of a kidney, which is the reason it is sometimes called a "kidney-bean." If you take the trouble to examine one of these ordinary beans, first of all you would find it has a coat which is of a reddish-brown colour, marked with a number of peculiar stripes. When you take that coat off, which you can very easily do, as it is very loosely attached, you will find that the bean is made up of two little lobes, which are attached together so as to open out as if they were hinged. Each of these is what we call a seed lobe. It is called also by a very big word, but we don't want to use any more of these than we can possibly help. The most wonderful thing of all we find packed away inside in the shape of a little body, which comes down in a somewhat pointed fashion. This little body consists of three parts, a pointed part, a neck, and a somewhat leaf-like part, perfectly white, which is to grow up into the stem of the bean plant. It is the embryo bean, and all the rest of the great seed lobes will have nothing to do with the formation of the future plant directly; they are simply a store of nutriment nature has provided for the nurture of the little embyro plant till it is big enough to take care of itself. The first lesson we may learn is, that, as a general rule, wherever nature forms a seed, a great part of that seed is intended for the nourishment of the little embryo inside. This, then, is what we find in the ordinary bean seed—a coat, under which we find two seed-lobes, and inside these a little embryo plant consisting of three parts. I will tell you presently what happens to these parts when they are put in the ground, but I just want to take you back a little in the history of that seed, in order that you may see exactly how it had its origin.

If you take up any flower—for our illustration we will take the flower of the bean plant—you cannot help noticing that there is something very beautiful about the parts of which it is composed. First of all, you will find underneath the coloured part of the flower a kind of cup, usually green. It is called a cup—or, rather, by the Greek word *calyx*, which means the same—formed of five little green leaves, not always five, but so it is in the case of the bean plant. Next we have the coloured part of the flower, which is made up of five separate leaves. In the bean plant these leaves are of a bright scarlet; they form that part of the flower which pleases the eyes with its beautiful hues. These two parts—the little green cup and the little scarlet crown, as it is called—are not really essential parts of the flower; the seed is in no way formed from them, still they perform a very important function by attracting insects to the flowers, as well as conducing to the beautifying of the landscape. Inside the flower you will find a number of little tiny stems, which have rounded heads. These little heads are really little bags or sacs, and these contain that usually yellow dust which the bees come after. The bees get right down into the flower, and this dust sticks all about their legs, whereupon they carry it home, and of it make honey.

Inside this we usually find a greenish-looking, somewhat oval organ. You will have to part the little stems I mentioned in order to see it. This is really the part of the flower which subsequently forms the pod and contains the seed. Inside that there is a number of little tiny round things in the case of the bean, which eventually develop into seed. Each one of these, being enlarged, contains inside a number of small bladder-like bodies, which we call cells; but one of these is a very important one. Just at the top of the double coat of this little embryo seed is a hole, which is called the "little gate." You will see the object of that shortly. When those little sacs which contain the yellow dust, the so-called pollen, of which the bees are so fond, get ripe, the pollen falls on the top of this central green "pistil," as it is called. The little grain of pollen begins to grow, and a little body comes out, which gradually gets longer, and eventually it grows right down to one of those little vesicles, goes in at the little gate, and then gets right down to the big cell at the bottom, and there it stops. I must just tell you that that cell is made up of a substance which is found to have about the same chemical composition, and is always found as the essential constituent of every living being—a substance which we call protoplasm. This is the one big word I ask you to allow me to use; it simply means "that which is first formed;" and this is the simple living material that is found as an essential constituent of every living thing, plant or animal.

We have now got as far as the growth of that pollen tube into this embryo cell, having touched which immediately there is set up a wonderful series of processes by which the seed of the perfect plant is formed. The first thing that takes place is, that the cell begins to divide into two, very much in the shape of an hour-glass. These divide into two again, and break away gradually, so that we get four cells instead of one. This process goes on until that single cell is converted into a whole mass of cells; at the same time, the thing is growing and growing in some wonderful way which I cannot tell you anything at all about. However, from these little bladder-like cells we have formed this little embryo plant and the seed lobes. The latter contain starch and other nutritious material, and the little embryo plant is that which is to grow up into the bean plant itself. I wish particularly to impress this upon you—that at the first there was only a single bladder-like body, a single protoplasmic cell, and so it has been, by what we call cell-division and multiplication, converted into this, comparatively speaking, very complex structure.

Then, you know, the bean seed is taken care of until the proper time arrives. No further change takes place until it is put into the ground, when, being influenced by warmth and moisture, it begins to swell. Then the seed lobes burst the coat which surrounds them, and a little root begins to grow downwards, and throw off little filaments, which form the roots of the plant, and then another part begins to grow upwards, forming the rudimentary stem, which grows higher and higher. Then of course leaves and branches grow out, and eventually we have the flower, and again we have the seed formed just in the same manner I described just now. Just think of what wonderful power must be locked up in that little body in the seed, and I must confess that, when I look at this bean, and after examining this little embryo through the microscope, find I can detect no difference between these little rootlets and that little stem, and try to conceive why, when the seed is put in the ground, one should grow down and the other grow up—when I think of how such a thing can be, what can be the causes of the difference in the direction which these two parts take, and the character of the organs they give off, I am entirely lost in wonder, and I think you will agree with me that even in such a common object as a bean plant there is food for a lifetime of study and wonder.

Having given you some idea as to how the plant begins to grow, I should like to say a few words about the manner in which it lives, because that is an important matter to ourselves. I suppose you all know that if you examine any ordinary plant—for this bean plant is only a type of a large number of flowering plants—you will find that those parts of it which are below, in the ground, are always white, and those which are above the ground are green, with the exception of the flowers, which are variously coloured. This greenness of the plant above the ground is a very interesting and peculiar fact. That green colouring matter, which imparts such beautiful tints of green to the various plants we see about us, can only be developed under the influence of light. If you were to put a plant in a cellar, and keep it down there, it would very quickly become as you and I would become under similar circumstances—very pale, and would never be in any way green. If you put the plant out, even in such murky air as we get here in Drury-lane, it becomes green. The existence of this greenness in plants is of very important use to the plant itself, and also, little as you may think it, of very important benefit to ourselves.

I know you have had chemistry lectures here, and you may have heard of two substances—gases, one called oxygen, and the other carbonic acid gas. Oxygen forms about one-fifth of the air we breathe, and it is that part of the air which helps to keep us alive. There is another component part called nitrogen, which dilutes the oxygen, a superabundance of which would cause us to live too fast, and would cause the gas burners, as well as the gas, in this room to burn. The other gas, carbonic acid gas, is made up partly of oxygen and partly of carbon, which is only another word for charcoal; and although carbon is a very wholesome thing, and oxygen is a very highly useful and beneficial gas; yet, strange to say, carbon and oxygen locked together form one of the most deadly poisons that can be produced—it is the choke-damp of which the miner is so justly afraid. This gas should exist in the air only in extremely minute proportions, something like five parts in 10,000; then, of course, it is so small as to be practically harmless. Now, it so happens that the very thing, carbonic acid gas, which is so injurious to all kinds of animal life, is just the very body that this green colouring matter lays hold of.

You may know that you and I, and all other animals, every time we breathe, are constantly throwing into the air a vast quantity of this gas, and taking a large quantity of oxygen out of it. We are making the air impure by throwing into it carbonic acid gas and taking out oxygen. Vast as is the volume of the atmosphere with which we are surrounded, it is evident that at some time or other we should get to the end of all the oxygen, and we should have carbonic acid gas in its place, though long before that we should have ceased to exist—10 per cent. of it in the atmosphere being absolutely fatal. And here we come to one of the grandest provisions of nature. This green colouring matter takes out of the air the very carbonic acid gas we are throwing into it; part of it, the carbon, being used by the plant as food, while the oxygen is put back into the air. So we see that the balance is kept up by these green plants, which are constantly drawing the carbonic acid gas from the air, and breaking it up into its two constituents, using the carbon as food, and purifying the air by restoring its oxygen. I think I have now justified myself in saying that the green colouring matter in plants was a great benefit to us as well as to plants.

I must tell you that this process only goes on during daylight, for in the night the opposite is going on. At all times the plant uses oxygen and gives out carbonic acid, but the effect of that process which takes places in the day is greater than that taking place both night and day, consequently the balance in the day-time is on the side of the giving out of oxygen and the taking in of carbonic acid gas. It is just the same as with a man with a large family, who receives, perhaps, 18s. a week. He is constantly taking money every week, and constantly spending it, and, unfortunately, sometimes the expending gets greatly in advance of the taking, consequently the balance is frequently on the part of spending. Just in the same way, the quantity of carbonic acid gas taken in is a great deal more than that given out. This thing is rather difficult to make plain to you. As soon as night comes on, one of these processes stops, the other does not; that is to say, the purifying of the air, by the plant giving off oxygen, ceases; and the other process, the making of the air impure in the same manner as animals make it impure, is going on. Now you will see why it is unhealthy to have plants in a bedroom. During the night they are doing the same as you are; using up the oxygen, so necessary to ourselves, and giving off poisonous carbonic acid gas. This I hope you will understand clearly.

Just a word or two, now, about the feeding of plants, *i.e.*, the way in which they obtain their nutriment. This carbon, of course, is part of their food, and then, as you know, the roots of the plant draw up a considerable amount of nutriment from the soil. The rain descends and dissolves certain salts of lime, magnesia, potash, soda, &c., and these are sucked up in a state of solution by the little tiny ends of the rootlets, and then, by a process which we do not quite understand all about, it gradually rises to the stem, and circulates to the edges of the leaves. There the water evaporates, and the solid material is left behind. Then, again, there is going on a double circulation, upwards and downwards. I will just tell you what we think is the cause, perhaps, of this circulation. I suppose you know that if you want to get a man along, presuming he is not able to get along himself, you can either push him or pull him. A combination of these two means—pushing and hauling—is what probably takes place in a plant. The material collected by the plant from the earth wants to find room, and pushes that which is before it, there being thus a tendency for it to ascend. We also see that, by reason of evaporation, there is a pulling force, inasmuch as the constant evaporation tends to leave a kind of vacuum, leaving room for fresh material to come along. This is, we believe, why sap rises in trees and plants.

We have seen, then, how a common bean arises, how the seed is formed, including that of the various cells of which the seeds are formed, until eventually we have the plant itself. We have seen, too, how it feeds, and how, like everything else in this world, having a certain portion of work to do, it does that work, producing a seed similar to that from which it started, and then goes its way. Such is the life-history of a plant. I have been describing an ordinary bean, but you may take that as an unfailing type of a very large number of plants which come under your observation; for, although there may seem at first sight a very great difference in the mode of production and mode of growth, yet, when we come to examine them, we find an extreme similarity, in some cases identity, with that mode of development which exists in the case of the bean I have been speaking about. Whatever else you may carry away with you to-night, I trust you will take away a little information as to how a plant grows, and then these words will never be applicable to you which the poet uses of Peter Bell, when he says—

> " A primrose by the river's brim,
> A yellow primrose was to him,
> And it was nothing more."

And for the future you will see in every blade of grass that springs beneath your feet, in every wave of those beautiful trees which add so much to the beauty and splendour of the landscape, in every ear of corn that bends beneath the summer breeze, and in the little tiny flowerets that grow upon your window-sill, something to tell you of the fair and beautiful land far away from London smoke and grime; and they will all be eloquent in meaning, and rich in a truth and a beauty of which you have never dreamed before.

I wish now to take you into the animal world, and in doing so I think, perhaps, I had better say a little about that which makes the difference between an animal and a plant. I suppose you will think, at first sight, that is a very easy question to answer, but perhaps you may be induced to modify your opinion in a minute or two. Of course, we all know, when we see a donkey and a haystack, which belongs to the animal and which to the vegetable kingdom; but as we get lower down in the scale we gradually seem to get into a sort of " no man's land," in which we find creatures which are as much like animals as plants, so that you really don't know what to say about them. It is only after a very considerable amount of thought and study on the part of some of our great naturalists that it has been found possible to define the distinction between a plant and an animal. The distinction is just this—although even now that is objected to by some: a plant can get its food from dead or inorganic matter, for, as I told you, a plant sucks up from the soil certain salts, and it also feeds upon carbonic acid gas, which is also dead material. No animal can do that; an animal must have for its food some material which has been living before, and some, as you know, are not at all particular in this respect. Every animal must have for its food some organic matter — that is, material that has been alive. We ourselves, for instance, live upon animal and vegetable food; no man could sit down and drink, unless by way of medicine, salts of lime, potash, &c.; he would soon cease to be a man if he did. He can do very well on animal and vegetable food—some people say upon vegetable food alone, but I don't think this is right; we should, in my opinion, live upon both. However, this is the distinction which I should like you to remember: an animal must have its protoplasm ready-made, whereas a plant can get its protoplasm from material that has never been living at all.

The object about which I am going to speak first of all is that very common one—a common hen's egg. You know in an ordinary egg we get outside a shell, which is really a kind of network of fibres, in which are deposited certain salts of lime, mostly of what is called carbonate of lime; this makes a hard, firm cover, or case, for the egg. When we break the egg open, we find, if we are very careful, that it is lined with a very delicate white, peculiar membrane, called the shell membrane, and then you will find, on carefully examining it, that, although at first sight it appears to be only a single one, it is really double. This is easily evidenced by the fact that when an egg gets two or three days old, these two membranes tend to separate at the broad end of the egg, and leave a cavity filled with air, owing to evaporation of the white of the egg through its shell. Of course, you know that the development of this air-cavity between these two layers of membrane enables the careful housewife to test the freshness of the egg, for you know that if on holding up an egg to the light you can detect a little spot at the top, it is not quite so new-laid as one might wish. You will notice this more particularly after boiling an egg.

Then you know, in the middle you get a round yellow mass, enclosed by a very delicate membrane, which very easily wrinkles. This is the yolk of the egg; and this yolk is really made up of minute cells. Then you notice on each side of the yolk a kind of twisted, whitish matter, which has a very different origin and use to that which is usually attributed to it. These two bodies really act as little elastic buffers to keep the yolk in a middle position in the white of the egg, so as not to allow it to go against the side and so get broken. That is the true nature of these, not that which is usually ascribed to them. They are called by a long name which means "hailstones," because, when you look at them through a glass you will see a number of little white dots, which by a slight stretch of the imagination appear like hailstones. Round the yolk we have the white or albumen, which to some extent serves only as another coat outside the yolk, which is really the essential part of the egg.

And now there is in the yolk a very important object which you have perhaps never noticed. Next time you buy an egg, look at the yolk and you will see a little round disc, only about three-eighths of an inch across, and that generally has the appearance of having a whitish border and an inner space which is quite clear. That little thin plate of matter, never more than about three-eighths of an inch across, is that which is going to turn into the perfect chick; that, and nothing else, for all the rest of the yolk is going to be used up, in the same manner as the lobes of a bean seed, as food, until the chick is old enough to look after itself. If you examine that under the microscope, that wonderful instrument which, like the fabled casket of the magician in the Eastern tale, brings into view the hidden riches of the universe, you will find it made up of little tiny cells, very much like those little cells which we found in the embryo bean-plant, and then you will find that these cells are arranged in two layers, just as in the case of the bean-plant. And now I must take you back in the history of that hen's egg, in order that you may thoroughly understand its origin.

I dare say some of you have seen, at one time or other, a fowl cut open, and that, if it be a "laying" hen, a little mass of yellow grape-like bodies are found in the body of the hen, which you commonly call the "egg bag." Each one of these little sacs which you see in it contains what will subsequently develop into an egg. We will take one of these capsules, and describe just what would be seen in it. Inside the capsule is a yellow sphere, inside that there is a little tiny disc, inside that disc a little tiny bladder-like cell, and inside that again is a tiny spot. When that capsule is quite ripe it bursts, and then is set free an egg, or ovum, as it is called. These two little things then disappear, and that little tiny disc, which is only one single cell to start with, undergoes a most important change. First of all, if we watch it carefully, we should see a little furrow come across it; gradually that furrow extends, so that you have the little disc cut up into two. Then it begins to send out processes from its centre, and very soon you get it cut up into a number of somewhat irregular segments, each of which becomes a perfect cell. The division goes on in this way, until eventually this single cell is cut up into a number of little tiny cells. Just the same as is going on on the surface is going on underneath, and so we get a mass of cells, which arrange themselves in layers to form the little disc which you find in the new-laid egg.

This egg then passes down a long tube called the oviduct, which conveys it to the exterior, and as it goes down all these other structures are added to it. When it starts it only consists of this little ovum with its disc, but as it gets a little way down the tube the white is put round; then those twisted cords, which get twisted on account of the manner in which the ovum slides down the tube. When the ovum gets into the third part of the duct, the shell membrane is added, and then in the last part the shell itself is deposited. Here the egg lies generally from twelve to twenty hours, until the shell gets thoroughly hard, and then, finally, it passes out, or is, as we say, "laid."

Having now got our new-laid egg, we know that if the egg is not submitted to warmth, as in artificial hatching, or put under a hen, nothing further takes place; but if put under a hen, or submitted to an artificial method of hatching, a wonderful series of processes is set up, of which I will try to give you a brief, rough outline. You can easily see, I think, that however much you may look at that egg, and think about it, you cannot get the slightest idea as to how it is to become a chick, with wings, legs, brain, nerves, heart, &c. The first thing that happens is that the little disc, the yolk to which I have alluded as having two layers, has added to it a third. These three layers are distinguished by hard names, but it will be sufficient for our purpose if I call them the top layer, the middle layer, and the bottom layer. I shall have to say something about these layers, for this reason, that each one has to form a particular part of the chick. The upper layer is going to form the greater part of the organs of sense—the skin, brain, spinal cord, and nerves; the bottom layer will form the whole of the intestines and the stomach, while the middle layer will form the heart and the blood vessels, and there also will grow out from it the lungs, liver, &c.

And now I wish you to understand that we have in the diagram on the black board simply the yolk of the egg, leaving aside altogether the albumen, with a section taken through it; therefore, on the top we should see the thin plate-like disc already referred to. The first thing that happens is the folding-off of this disc from the rest of the yolk. At each end of the disc appears a notch or groove, and these grooves grow towards each other so as to cut off a small part of the ovum from the rest. Grooves also grow inwards from each side. This is a thing which, perhaps, you may have some difficulty in understanding, but I must tell you that the top part (the disc) is going to grow at the expense of the lower part—that as the upper part gets larger the lower part gets smaller, and just on the day before the chick comes out of the shell the small portion left is popped into the chick's intestines. In order that you may perfectly understand this, I will proceed to tell you how this little chick is "marked off" from the rest of the yolk.

And now I have to speak to you as to how is formed that wonderful series of structures—the nerves, skin, brain, and the spinal cord—which runs down the backbone. The first thing which happens when the hen sits on the eggs is the folding-off the embryo, which, looked at from the top, is pear-shaped. Imagining that this has taken place, we next watch for the appearance of a little tiny groove coming down what I may call the hinder part of the chick that is to be. At one time this groove was supposed to be the foundation of the canal which forms in front the head and behind the spinal canal; but now it is known that this goes away, we don't know where, and behind it there comes another groove, which gets deeper and deeper, and forms the beginning of this spinal canal and in front the head. The sides which are formed by this groove grow upwards and lean towards each other, and eventually join, thus making a complete canal. That is just how the front of the head and the spinal canal is formed, which is one of the most wonderful organs in the body.

Every animal, including our little chick, has a backbone, made up of a number of small bones. This is foreshadowed in this way. In this upper layer there is a plate of material which has not split; that gradually begins to be marked out into little tiny plates, each one of which is eventually converted into one of the bones forming the backbone, and part of the nerves and muscles are formed from the same source.

Now, just one other point, which, perhaps, is a little difficult, but nevertheless extremely interesting. If you were to cut a chicken across in two about the middle region of the back, you would find down below different organs, the heart, &c., the ribs, the backbone, and a tube containing the spinal cord. Then, of course, supposing the animal to be quite perfect, you would find part of the food canal going through it. As the process of development goes on, just as I showed you just now in the case of the upper layer, these middle and lower layers begin to get furrowed. A part of the one unites with the other, and *vice versa*, to form a third tube, so that instead of having this little disc, consisting of three layers, we have it now consisting of two, so that there is now one tube answering to the food canal, and another outside which forms the body walls. Now, you see, we have the general lines of the future chick laid down. First of all, we have the separation of the embryo from the food part of the yolk, then the formation of backbone, skin, spinal canal and nerves, &c., and the body walls. As I have already said, the lungs, liver, and other similar organs grow out of this central canal subsequently. A most curious thing is the formation of the legs and wings, which begin to grow out of the side, looking just like little tiny leaves; the hinder limbs come out first, and then they gradually take on their respective characteristics which each possesses. There is just one other thing I should like to say a few words about, and that is the formation of the heart. The heart, first of all, is simply a little mass of cells, though I want you to understand, too, that when we started the egg which was to form the chick was nothing more than a mass of these little cells, and out of these little cells we get all the wonderful structures of which I have been speaking. In the case of the heart, at a very early period, about the fifth day, a mass of cells appear all in a lump, and that constitutes the rudimentary heart. These gradually develop, but long before the heart is perfected it begins to beat, gradually at first, and then faster and faster, until, at the time of hatching, it is thoroughly formed, and pulsates with great rapidity. Then a number of cells are formed in different parts, which send out little processes, and then you get a number of these all over the body. They eventually get connected with the heart, and thus we get the blood vessels in this wonderful way—first of all formed, like everything else, out of a small mass of little tiny cells. The blood itself is also formed out of cells. We go on in this way, until the various structures in the chick are formed, and then come the feathers and claws. These latter are simply outgrowths, just the same thing as your nails and hair. They are simply outgrowths of the outer layer of the skin; then, as you know, the chick, finding itself ready to come out into the world, gradually breaks its way through the shell, and eventually comes out a perfect chick. It grows up gradually and becomes a fowl, and, just as in the case of the bean-plant, we began with a seed and ended with a seed, so, in the case of the fowl, we begin with an egg and end with an egg.

This is the life-history of the second object of which I had to speak, and it possesses for us this interest, that it is a type, with certain modifications, of the development of every living animal upon this earth, not excepting man himself. The very tiniest animals of which we know—and I might tell you of one that is nothing more than a simple mass of jelly—consisted of a cell like the one with which we started, and the most complicated animal, man himself, simply consists of various structures which have arisen from the growth and development and different modifications of similar cells.

I must apologise for having kept you so long, but I feel certain that I have said enough to you to-night to show you that the study of living beings is one of the most interesting, one of the grandest, one of the most beautiful subjects in which the mind of man can possibly engage; and I sincerely trust that when, in days to come, you wander through verdant fields and woodland glades, and listen to the many-voiced hymn of nature which she sings, or stand on the sea-shore, and watch and listen to the waves as with gentle murmurings they ripple on the beach, or, it may be, dash in thunder at your feet, there will mingle with carol of bird and hum of insect, and even with that wild ocean music, thoughts which shall tell of that vast and wondrous life which is around us on every hand. Moreover, there is one other point to which I would direct your very particular attention—a point which seems to me amazingly interesting. It is the exact nature of that little tiny cell from which, as we see, the hen's egg and the chick itself is built up, and whose development is just the same as that little tiny cell which produces the bean-seed. This latter was composed of protoplasm; so, too, was that little cell from which the chick sprung; and what is true of it is true of every other living creature.

And when I remember that, at the very bottom of the animal scale, there exists a minute organism which may be best described as a spot of animated jelly, which, too, is protoplasm, and which, nevertheless, in the true sense of the words, lives and moves and has its being, and that, therefore, by virtue of man's origin, it can claim kinship—it, the lowest, with man, the highest; that moreover, for myriads of ages, colonies of minute animals, which are little else than protoplasm, have been toiling beneath the deep sea, and have reared huge piles of rock beside which, as mere monuments of industry, man's proudest achievements must hide their diminished heads; that from just such specks of protoplasm must have been developed all the living beings, plant and animal, which have peopled this world from the very dawn of existence to the present time; that from just such specks of protoplasm every member of the human family now upon this earth, the highest and the lowest, the mightiest and the meanest, the wisest and the simplest, have been developed, I confess that in the whole realm of nature, animate or inanimate, I know of no subject else of such surpassing wonder, none which can wake such deep emotion, none which so clearly tells me of man's insignificance and nature's power, none which so fully shows me the grandeur, the potency, the sublimity of that mysterious agency which we, in our ignorance, call "the laws of nature."

VIII.

COAL.

I PRESUME most of us present have at some time or another been struck by the comparatively insignificant size of our own country, and have probably been led to wonder how it is that a nation inhabiting so small a portion of the earth's surface should, nevertheless, be so far ahead of all others in material wealth, in the true spirit of commercial enterprise, in intellectual vigour, freedom of thought, and in the possession of all the appliances of civilised life. When we come to examine the cause of this pre-eminence, we, of course, have to consider a large variety of circumstances. For instance, the position and natural features of our country have undoubtedly exercised a very great influence upon the progress of our nation. Surrounded as it is on every hand by the sea, intersected by a close network of rivers, the majority of which are navigable for a large part of their course, so that every part of the country is within easy reach of communication with the sea, and by the sea, of course, with every part of the world. These, and similar advantages, have no doubt tended to engender in the minds of our countrymen that spirit of adventure, that desire to know something of the lands beyond the deep blue sea, and, above all, that perseverance and pluck, which have so long been the characteristics of the British nation.

But, independently of these advantages and others like them, there can be no doubt that a very important item in the progress of our country is the immense amount of mineral wealth with which it is endowed, and of that mineral wealth the most important item is decidedly coal. It is about coal —about the manner in which it is obtained from beneath the surface, about its true nature, the manner in which it is formed, and how it got where we find it—that I wish to speak, and ask your kind attention for a short time to-night.

Of course, everybody here knows what coal is like in outward appearance, and unfortunately the past severe winter —let us hope it really is past—has made us very familiar with the difficulty of getting it, and of the very great need for burning it as a source of warmth; therefore, I shall not waste your time by any description of the appearance of coal, but shall at once ask your attention to the position of our chief coalfields, and the manner in which it is got from beneath the surface of the earth. Therefore, my assistant will now kindly throw upon the screen a map of England, which will show us the position of our principal coal-fields. Our map also comprises a part of Scotland and a small piece of Ireland. In the latter country there is a considerable extent of surface which contains coal beneath it, but the coal is poor in quality and extremely thin, and so we don't get much from Ireland. Turning to our own country, we find, of course, that the principal coal-fields are those of Lancashire, Yorkshire, with part of Scotland, and the South of Wales; and in addition to these we have others in Somersetshire, and in Leicestershire and South Staffordshire we have a thick coal known as the "ten-foot" coal. Also in the Forest of Dean we have a little. Omitting the smaller coal-fields, the principal sources of our supply are South Wales, Lancashire, and Yorkshire.

It is estimated that we have in the British Isles an area of something like 5400 square miles of coal. These so-called coal-measures, which term I shall presently explain, comprise a considerable amount of rock, limestone, sandstone, shale, and so forth, beside the true coal. The coal-measures are sometimes several thousand feet in thickness, sometimes as much as 10,000 or 11,000 feet. In the group of rocks forming a coal-measure we have, perhaps, only 35 to 40 feet of workable coal. When we consider the immense thickness of the coal-measures themselves, in which the coal is embedded, and the immense amount of labour which must be employed in order to get the coal from the other rocks, together with the fact that in this country there are about 5400 square miles of these coal-measures, yet all this is very insignificant when compared with the coal-fields which are found in other parts of the world, especially in America. In North America alone there are in round numbers something like 200,000 square miles of coal; and if we take Belgium as the country containing the least amount of coal, we find in England about five times as much as they have there, while in America they have 111 times as much, so that you see the proportion between the coal of England and that of North America is as 5 to 111. Although we have to devote our time to the consideration of our own coal-fields, nevertheless I have mentioned these facts, because there has been some amount of discussion as to the rate at which we use our coal. It is certain that over 100 million tons of coal are brought to the surface every year in England, and of course, whatever may be the exact amount of coal in England—and although a good many guesses, scientific ones too, have been made, yet we cannot say exactly how much there is—there must some day come an end to it, and when that comes there can be no doubt that England will cease to hold the position she does as the first manufacturing country in the world.

We have next to show you the appearance of a coal mine on the surface. You know, of course, that when coal is supposed to exist beneath the surface in any particular region, borings are made; and then when the coal is found, supposing the search to be successful, shafts are sunk. As regards the workings which are carried on under the ground, we find one of the main workings running generally north and south, while another intersects it running from east to west, and then from these main workings a number of subsidiary ones penetrate in all directions into the seam of coal. Certain works are, of course, necessary upon the surface, and these are, first of all, an engine or engines, with the proper buildings to contain them.

Then, of course, the miners have to be taken down by means of a cage or other appurtenance, and the coal brought up. In our picture, over the shaft we see a wheel over which passes an endless chain with a cage at each end, which chain is worked by means of a steam-engine, so that while one cage is at the bottom, the other is at the top; and while one is being emptied above, the other is being refilled below. This will give us a general idea of the appearance of a colliery above ground, which, however, is very insignificant as compared with the workings underground, the latter often extending for several miles. One thing we may as well notice—viz., that a railway runs close by the side of the colliery. This is very generally the case, so that there is no cost for carrying the coal from the colliery to the line of railway. If you stand upon a hill in Yorkshire, you can always trace the line of railway by the position of the collieries.

Our next picture will take us another step towards getting down below. I may tell you that not long since, in order that I might be able more thoroughly to lecture upon this subject, I paid a visit to one of the principal collieries in Yorkshire. The going down the shaft is effected in various ways in different collieries, and here we have a representation of some colliers going down in what is called a basket, though it is really a sort of tub. This mode is not much practised now, as it has given way to another form, which not only serves for the conveyance of the miners downwards and upwards to and from the workings, but also serves for conveyance of the coal upwards and the empty trucks downwards. Here we have a form of what is called a double cage. There are sometimes two platforms to these cages, which are open at both ends, and the sides fastened together strongly with iron bars. This cage exactly fits the shaft, so that it can move upwards and downwards freely. It is also attached to guides, which are strong wire ropes, over which the cage slides in its passage. There are two such cages, one going down, the other up. Just round the top of the shaft there is put an iron fencing to prevent any one falling down. Many accidents have occurred from the want of this precaution. In this fencing gates are fixed, where the ends of the cage come; and when the latter arrives at the top, certain projections catch hold of these gates and lift them up above the top of the cage, thus leaving it open at both ends. Then at one end there are two boys stationed, who push on the empty trucks, while at the other there are a couple of men who pull off the full trucks, which are then put on to a weighing machine and sent off on the line. As soon as the empty trucks are pushed on, down goes the cage and up comes the other one, when the same process is repeated.

Just in the same sort of cage as that it was that I went down the shaft of the Roundwood Colliery last March. Instead of taking down a couple of empty trucks, I, and the man in whose care I was put, went down. All that can be said about going down is that it is quick. That is about the best thing you can say about it, and the feeling engendered is one that can be far better imagined than described. The floor seems to give way beneath you, and a feeling comes on which is very much like sea-sickness, only it is worse. To give you an idea of the process, I may tell you that in a colliery about 600ft. deep these cages go down and up four times in a minuté, so you see it is just like falling down. When they take a visitor down they generally stop the speed of the engine in order to take him down gently, but in my case I went down quickly. The engines used are so beautifully worked that the cages go down as softly as possible.

Arrived at the bottom you find that you have got down into a narrow passage twenty feet wide, and about six feet high, so that you can comfortably walk upright. This is one of the main ways of the colliery, and you find that it is laid with a double line of rails, upon which you will find coming along a number of small trucks laden with coal. You are provided, of course, with a patent safety lamp, which I shall speak of presently. With this lamp you have to find your way about the colliery, everything, of course, being in darkness. The men who are working are all provided with similar lamps. The air, owing to the splendid ventilation which is carried out, is perfectly good; better than that which we get in some parts of this city. There is none of that feeling of oppression or desire to get to the top you might think you would experience. As far as your eye can stretch, you see this main way before you. Then, if you go along farther, you will find that there is another way going across it at right angles. Accompanied by my guide I went along this way, and the first thing that struck my notice was the manner in which the trucks are worked. There is a large engine-room down below, in which are a pair of magnificent engines. These engines work on large drums an endless wire rope, which runs, guided by pulleys, all round the mine, just in the middle of each line of tramway. The trucks, which are very small, are worked by boys, who sit upon the front of them. Each boy has a kind of clutch on a long stick, and when he wants to be drawn along, he simply clutches hold of the wire rope which is constantly moving round the mine. When he wishes to stop he simply unhitches his clutch, and then the trucks are taken to the foot of the shaft by horses.

I wish now to show you some pictures which will illustrate the manner in which the coal itself is got. In the first we see the miners working in a comparatively comfortable manner. In this case there is plenty of room for the men to stand upright. One man has an ordinary kind of crowbar, with which he is loosening the coal from the seam. Above, we have some of the rock which overlies the coal, and again below some other rock of which I shall speak presently which underlies the coal. As a general rule, the seams of coal are not above three or four feet thick. Sometimes we get it about nine or ten feet thick. This thickness, which is very remarkable, occurs in South Staffordshire coal. Another man is engaged in shovelling up the coal ready for the trucks. It will then be taken out of the workings by horses, or, in the case of small workings, by boys. It is then brought out into one of the principal sideways, when a number of trucks will be joined together so as to form a train, and taken along in the manner just described by this wire rope that goes all round the mine. Besides the main branch of this rope there are smaller ones, which can be hooked on or off as required, and boys are stationed at each point to do so. The miners in our picture, we see, are only working by the light shed by their lamps.

That, of course, is a comparatively comfortable way of working. It is true the miners are a long way beneath the surface of the earth, and shut out from the light of day, but they are not working in a cramped position, and I suppose they get used to it, and do not mind it much. But it is different in some of the smaller ways. Of course, as a general rule, the ways are made as lofty and as wide as possible, but in some instances it happens that the coal is only very small—it is very thin, and therefore the ways have to be made much smaller. In our next picture we have one of these narrow workings, probably about three feet high. There they have to work in very uncomfortable positions; crouching down, sitting on blocks of coal, working away with the pick. This very uncomfortable work is, I think, generally better paid for than the other, and the miners are generally very experienced men. It is a most striking and peculiar sight to observe these miners, dimly seen working in the bowels of the earth, by the glimmering light of their lamps shining upon the black walls around.

Our next picture has reference to another mode in which the coal is obtained. In some instances the rock has to be got rid of in order that the coal may be arrived at. In these cases recourse is had to blasting: a charge of gunpowder is inserted, ignited, and the rock is blown away. In our picture we see the men boring for the purpose of putting in a charge of powder. They light it, and then retire to a safe distance. An explosion shortly ensues, and then they go back and bore again. There is a machine for boring the coal, but this is generally the method employed.

Our next illustration gives us another idea as to how the coal is obtained from the seams. It requires a very great deal of care and skill upon the part of the managers and overseers sometimes to direct the miners in the proper direction. The coal generally lies in pretty regular and even seams, but occasionally, owing to revolutions of the earth's surface, such as those of which I spoke in previous lectures, the strata, or layers of the rocks in which the coal is embedded, have been shifted and ruptured. You will have a seam of coal running along, and after following it some distance it disappears, and in place of the coal you may find a hard limestone rock. Upon making an examination an experienced man or a geologist would find that the coal had probably been by some means pushed upwards several feet, or, it may be, downwards. They then set to work to clear away the superfluous rock, and so get to the coal again. These malformations of the coal strata are known as "faults," and they form a very great difficulty in the work of a colliery. In the one which I visited recently there is a large number of these faults; consequently it is a very difficult colliery to work.

Our next picture takes us a little further, and illustrates how the coal is got from the smaller workings, where the miners work out into the main ways. There these small trucks are used. Two boys are engaged in working them, one pushing and the other pulling. A lamp is stuck on the truck, which is pushed out to one of the sideways, and then taken by horses to a branch of the wire rope I mentioned before, and so on to the foot of the shaft. I think you will see from what I have told you that a miner's life must be a very arduous one, even if we leave out of it all possible dangers from explosions and other accidents; though with regard to explosions I must say they very often result from the fault of the miners themselves, and sometimes owing to the neglect of the employers.

A very important point to be considered is the ventilation of a mine. There must be a constant current of air going through all the workings in order to get rid of the noxious gases, and also to give fresh air to the miners who are working in them. It very often happens that when an amount of gas is set free in a working, instead of having the work stopped for a day or two in order to have the mine thoroughly ventilated, it is allowed to accumulate, and then, perhaps, in some way or other a light gets near it, and then, of course, off it goes. The old way of ventilating a mine is represented in the diagram before us, which represents the surface of the earth above the mine. Here at the top we have a large furnace, which is kept constantly burning night and day. The fire kept up is enormous; in fact, if you open one of the doors to look in, you don't look long. The effect of these fires is, upon a large scale, just the same as that of a fire in a room. It promotes, of course, a very powerful current of air up what is known as the "up-take" shaft. Then, in order to replace the air which is thus drawn up, there must necessarily be a strong current of air descending the other shaft, which is known as the "down-take" shaft. You see in that way a thorough current of air is constantly driven through the workings.

It is a very difficult matter sometimes to get the air to go through all the workings, especially when these workings are very intricate. It would be comparatively easy to get the air just through the main ways, but then the side ways would be altogether destitute of ventilation. In order to manage this all those sideways have large swing doors, and these are so arranged as to prevent the current of air going down any one part direct; they make it go round and come back, so as to traverse the whole working. At each of these doors a boy is stationed to open and shut it as may be required. Then, again, in some of the other ways you may find, instead of swing doors, immense tarpaulins and blankets flung across for the same purpose: these have to be lifted up when any one wishes to pass through. Sufficient provision is made for the circulation of fresh air throughout a mine by this means, but a more efficient way is by means of what is known as the "Fan," of which I shall show you a diagram. In some mines they use both systems. This fan really consists of a wheel with a number of paddles, which is constantly worked by means of an engine at a very rapid rate. By means of this apparatus, a much more efficient way of ventilating a mine is obtained at a less cost than that of the furnace system, though, as I said, the one is often used in conjunction with the other.

If, then, ventilation is properly carried on, and if care is taken not to allow of any accumulation of poisonous gases, there would, of course, be no explosions at all; but then it is almost impossible to prevent every now and then a certain outflow of gas from the workings, especially when a new part of the seam is opened; therefore it is particularly necessary that every precaution should be taken against ignition of these explosive gases. I may tell you that the gas which explodes in a coal mine is very similar to the common gas which we burn for light. That gas, as you know, will not explode until it is mixed with air; and, moreover, it will not explode unless a light is applied to it. As soon as the gas is set free from the coal it necessarily gets mixed with the air which is in the mine, and therefore it is necessary that no light whatever should be allowed to come near it. Consequently the miner is provided with a lamp, which was invented by Sir Humphrey Davy, and is known as the Davy Patent Safety Lamp. Unfortunately, the miners, like all people who are constantly employed in businesses which are risky, forget, or wilfully neglect to observe these necessary precautions. Sometimes they open their lamps, and then, if there is any gas about, an explosion occurs. In many mines the lamps are locked, but even then the miners will take matches down with them, and strike them to light their pipes. It may be that they do this in safety fifty times, but on the fifty-first time there may be some gas about, and so by the careless, culpable neglect of one man hundreds of lives may be sacrificed, and thousands of women and children be made widows and orphans.

In our next view we have a terrible scene at the top of a mine after an explosion. You have often read in the newspapers of an explosion of gas in a room, caused perhaps by the absurd, not to say idiotic, practice of going to find out an escape of gas with a light. An explosion of this sort causes a large destruction of property, and very often death. Just then imagine what would be the effect of an enormous volume of such gas when a light is applied to it. The explosion must be something terrific. When I was in Yorkshire for the purpose of visiting a coal mine, I was told by a gentleman that on the occasion of an explosion which had taken place recently, although his place is nearly four miles from the colliery where the explosion took place, he being just about to sit down to dinner, the dining-table was overturned, and himself very nearly knocked down. You can, perhaps, imagine what must have been the force of that explosion.

Another great danger that follows an explosion, supposing the miners to have been so fortunate as to have escaped being burnt or killed, is what is known as the "choke-damp." This, the gas which is produced by the explosion, is the same which we, by breathing, are constantly pouring into the atmosphere; it is the same gas which makes us feel so faint and unwell when we are in a very crowded room or hot atmosphere.

We will now have a view of the Davy Safety Lamp, in order that I may explain its principles. I told you that the gas which is found in a mine will not explode unless a light or sufficient heat is brought near it. Here we have the Davy Lamp. It consists of a stand, and a glass cylinder surrounding the flame, and for ventilation the top is covered with wire gauze. The original Davy Lamp was all gauze, but this is the form now in general use. In order to explain the principle of the Davy Lamp, I will tell you that if you take a piece of wire gauze, and press it down on the top of a flame so that the flame can get through it, the heated gas, passing through the extremely fine meshes of the wire gauze, parts with a large quantity of its heat, and when the gas gets on the other side, it is no longer hot enough to be inflammable. That is just the simple principle of the Davy Lamp. You see as long as the lamp is properly managed there can be no possibility of an explosion; but, as I said before, some of the men will unscrew the top to light their pipes, &c. Of course it is very sad that such disasters as explosions should result from mere carelessness; but it is to be hoped that as education advances, and men get to see the real distress which is caused by their neglect, they will be more careful, and, in co-operation with the masters—for here co-operation is essentially necessary—they will do all they can to stop the lamentable accidents which occur from year to year.

One very curious thing one notices in a mine is the horses. When a horse once goes down a mine, he never comes up again until he is dead. The horses, however, get so used to being down below that they cannot bear the light. The cattle they have in mines are very fine, and their stables are beautifully built, forming a splendid contrast to the dirty and grimy workings. As you go along underground you have to be very careful to hide your lamp when you are near a horse, otherwise you will probably get a reminder from him that he doesn't like light, so you must respect his prejudices.

These are all the principal features in connection with the "getting" of the coal which I need bring before you. I have given you a few brief outlines of the difficulties and dangers in the way of a miner, and the way in which these difficulties are to a large extent overcome. You can easily see that the coal, once at the top of a mine, is very easily sent to any part of the country, or, if necessary, over the sea to its destination.

Now for a few words about what coal really is. First of all, I want just to point out to you how it is we find the rocks and various kinds of soil are arranged in the earth. We will now throw upon the screen a diagram which represents to you something of the appearance of the earth, if you were to make a section for a considerable distance through it, and the arrangement of the different strata. The latter, of course, differ in different parts of the country. You know that, in our own country, underneath the soil, which has been more recently deposited, more especially on the sea-coast there are immense quantities of chalk. Then, in addition to the chalk and ordinary limestone rocks, in some parts we get sandstone and what are called shales.

These latter are simply hardened clays. Then there are other various kinds of rock, which I need not bother you to mention to-night. Above all, we get coal, and it is about coal I want to speak; I want to show you how coal is hidden beneath the surface, and, if possible, how it got there.

You will notice that the rocks are laid down in a manner which resembles very much the layers of sand which you find upon the sea-shore. If you notice the latter, you will find the sand which has been deposited by successive tides is laid down in a series of layers, or, as we say, strata. Well now, wherever we find these rocks laid down in a manner precisely corresponding to the layers of sand on the sea-shore, we may reasonably conclude that these rocks were laid down under water, because we know of no other power besides water to do this. Moreover, we are justified further in this theory by finding in the rocks of limestone, sandstone, and even in the coal-measures, the ripple-marks which have been formed upon some ancient sea-beach, patches of shingle deposited by some ancient sea, and remains of animals which have been deposited beneath the water. In the coal-measures, as they are called, we find five kinds of rock; first of all, the rock known as limestone.

Limestone is the product of certain animals; sometimes it consists wholly of the skeletons, and sometimes only of the broken *débris* of the skeletons, of such animals. For instance, the lobster has his skeleton outside, not inside, and it contains a very large quantity of lime in the form of carbonate. When the animal dies its shell is deposited as limestone; gradually, of course, being hardened by the pressure of successive deposits.

Then, again, we find sandstone. This sandstone is deposited on the sea-shore; and wherever we find sandstone we know that we are near the surface of the main land, because, as you know, at present it is only near the sea-shore that we get sand deposited by the rivers, which are constantly pouring into the sea the sediment which they bring down from the land through which they have passed. By constant accumulation this sediment gets to a considerable thickness, and by the enormous pressure which is exercised upon it, especially the lower layers, it is very soon, comparatively speaking, converted into solid rock.

Another kind of rock is the shale. This consists, as I have before stated, of hardened mud, and must have been deposited in very shallow water just at the mouth of a river, or, in very many cases, of several rivers. Then we find the coal itself, and then we have always immediately underneath the coal a layer of material which is known as the "under-clay," which is particularly important and interesting to us to-night.

As to the origin of the coal itself, there is no doubt as to its being the remains of ancient vegetation. That coal which we burn in our fire-places, that coal which we use in our steam-engines, and use for so many manufacturing purposes to-day, was ages ago flourishing in the light of the sun as a forest, which in appearance would have been similar to a tropical forest of the present day. I shall presently show you some of the forms of vegetation of which the coal is formed.

We have a beautiful specimen here in a view of a number of tree ferns. We find tree ferns similar to these in New Zealand and other places. There are two kinds of trees in our picture, as indicated by the stems. One has a number of scales upon it, which make it look like a monster pine. The stem extends upward for a long way without any leaves, and is crowned at the top by a cluster of branches. These scales are really cicatrices, where branches have been formerly, and have fallen off. This tree is known by the somewhat long name of *Lepidodendron.* The other tree is also remarkable, not for scales, but for a number of fine leaves, and is known as the *Sigillaria.* We shall have a better example in another view. Then we have a number of trees and plants of a somewhat reedy character, such as grow in swamps. They are known as *Calamites*, from a Latin word meaning a reed. They are very similar in character to the rushes known as "mare's tails," but there is one important difference between the "mare's tail" and the *Calamites* of the coal period, for many of the latter reached a height of thirty to forty feet, while the former only attains a height of five or six. These other trees frequently reached a height of from forty to seventy feet.

Another view will show us something similar, but it will represent an ideal landscape of the coal period. There we see these immense *Lepidodendra*, the scale-like trees, and there also we have the *Sigillaria*, which name is derived from a Latin word meaning a seal, because the marks on the stem look very much like the impression of a seal. Then we have a number of tree ferns, and there are also a number of gigantic trees, very much like the palms of the Tropics. We find also a number of trees bearing cones, being so-called coniferous, or cone-bearing trees. Of such trees we believe the coal forests were in the olden time composed, and from various considerations to which I cannot fully refer now, but will speak of presently. It is pretty evident that these coal forests grew in swamps, just as in the present time, on the Mississippi in America and the Ganges in India, we have similar swamps. In addition to the trees I have mentioned, I may say that there were a number of trees allied to our club-mosses, with the exception that whereas the latter are of the length of our finger, the former were something like ten to twenty feet high—everything, you see, being on a gigantic scale. We should have found in these forests some animals, but only those of a very low order. Of course it was long before man came upon the scene, and we have reason to believe that it was long before birds appeared. In these gigantic forests would be only heard some low murmuring sounds from these lower animals; the chirp of the grasshopper; the cry of an animal similar to the present frog, and occasionally the splash of some of the larger lizard-like animals as they dashed in and out of the water. Beside these there would have mingled no other sound—no carol of birds, no sound of anything belonging to the higher creation, would have mingled with the sighing of the wind through the gigantic trees.

I told you that immediately underneath the coal there was a bed of matter which is known as the "under-clay." Now wherever you find coal you invariably find this under-clay. It is the presence of this under-clay, together with certain vegetable remains found in it, that has determined the exact character of the coal-measures. For a long time it was thought that the idea of the vegetable origin of coal was a mistake; but attention was drawn some years ago to the fact that in the under-clay there occurred a number of roots, which consisted usually of large discs, from each of which radiated about four large root-like branches. These divided into two, and into two again, and broke up eventually into a number of fine rootlets. Of these rootlets almost all of the under-clay is made up. For a long time it was not known to what these belonged. It was pretty certain that they were rootlets, and then some few years afterwards there was found in the coal-measures a tree with some of these roots attached; and this tree proved to be no other than the *Sigillaria*, of which I spoke just now.

It was thought that these rootlets found in the under-clay had nothing to do with any of the vegetable remains which are found in the coal itself. They were presumed to be a distinct fossil, and had a distinct name given to them; but it has been shown that these *Stigmaria*, as they are called, are merely the extensive rootlets of the gigantic trees, fifty, sixty, or seventy feet high, which existed in those days, which had long been known as a separate fossil.

Here, in our view, we have one of those trees shown as it was found. The other trees are not often found in an erect position, owing to disturbances in the land in the manner of which I spoke before. These disturbances were not sudden movements, but the gradual and silent movements which are constantly going on. These trees having been thrown down have become very often empty, and the inside filled with sand, and so you get a cast of the interior. Such trees have become fossilised and converted into coal.

Now, this shows us very conclusively indeed that coal has had a vegetable origin. One other form of vegetable remains which is found in the coal I must mention : I allude to the small cones which are found in extreme abundance in some kinds of coal. These have been determined by Huxley to be nothing else than the seed vessels of some cone-bearing tree, something similar to a fir. Huxley at one time thought that nearly the whole of the coal was made up of these little seed vessels, but it has been shown that in some kinds of coal found in different parts of the world they occur only to a limited extent. Therefore it is highly probable that they only form a portion of the coal. Although extremely numerous, these little seed vessels are very small ; they contain a large amount of what is called the *bituminous* matter, that material which gives the coal its flaming quality. In the "smokeless" coal these little vessels are not so abundant.

Our next view will just show us a few of the animal remains we find. The shells discovered are, to a certain extent, similar to those we find in the present day. A large number of the remains found in the coal are those of animals such as must have lived in shallow water ; therefore it justifies us in supposing, as I have already said, that the coal forest must have flourished in very shallow water. Another thing in favour of this view is the fact that if the trees of which I have spoken had been drifted about in deep water, they would have drifted about for a considerable distance without settling, whereas in shallow water they would simply lie as they fell. Those seed vessels of which I just now spoke are extremely small and light, and if they had been drifted by running water they would have been spread about, instead of being evenly and regularly deposited as we find them.

Here we have a very beautiful shell of a tribe known as the *ammonites*, which were very similar to the nautilus of the present day. The shell is divided into a number of little chambers, of which the animal occupied one at the end. As the animal grew his house got bigger—a very convenient thing indeed. Our houses are large enough for us when we start, but as we get on we find a difficulty in enlarging ours, which the *ammonite*, or nautilus, does not experience; and he occupies his house, too, without paying rent or taxes.

We will show you another one or two of these coral fossils, just to give you an idea of the life of the coral period, which was a very low form of life. There is one which is called a stone lily, because it is very much like the flower. This animal is a low type of organism, not very dissimilar to the corals of which I spoke some time ago. We have two or three forms of these *encrinites*, as they are called, and though they look like "stone lilies," they are not lilies, but remains of animals. A large number of fossils may be seen in the Geological Museum, Jermyn Street; and as I thought you would perhaps say, "Oh, it's all very well to put pictures on the screen," I have two or three specimens here in order to show you after the lecture.

Now, I think I have said enough about the nature of coal to give you some interest in the various changes which have been constantly taking place upon the surface of the earth. The coal, of course, was formed myriads of ages ago, and the various rocks we find with it point out what various changes have taken place in the arrangement of sea and land, one spot which at one time was dry land being at another time under the water, either fresh or salt. I would refer you, in order to get much information upon this and kindred subjects, to the Geological Museum.

I think you will see there is a large amount of interest and instruction to be gained even from a lump of coal. When we talk about coal, we must naturally say something about the colliers. I need not refer to the extreme bravery of these men. Some of the greatest and brightest acts of heroism the history of the world ever produced have, as you well know, sprung from a dusty, dirty colliery. There is a simple piece of poetry which you may, perhaps, have heard, but which will bear hearing again, about a collier's child, which I thought would prove a very fit conclusion to this lecture. Although it is very simple it will, at least, remind us that, grimy and dirty as a miner's work may be, shut out from the sun and the light of day nevertheless, they share the same feelings, and their hearts are touched by the same emotions, and they are knit together by the same cords of affection and love as those whose walk in life may be smoother, and whose occupations may be more pleasant and profitable. It is called

LITTLE JIM.

The cottage was a thatch'd one, the outside old and mean,
Yet everything within that cot was wondrous neat and clean ;
The night was dark and stormy, the wind was blowing wild—
A patient mother sat beside the death-bed of her child ;
A little worn-out creature, his once-bright eyes grown dim,—
It was a collier's only child, they call'd him "Little Jim."
And oh ! to see the briny tears fast flowing down her cheek,
As she offer'd up a prayer in thought she was afraid to speak,
Lest she might wake one she loved dearer far than her own life,
For she had all a mother's heart, had that poor collier's wife :
With hands uplifted, see, she kneels beside the sufferer's bed,
And prays that He will spare her boy, and take herself instead ;
She gets her answer from the child—soft fall these words from him,
"Mother, the angels do so smile, and beckon Little Jim ;

I have no pain, dear mother, now ; but oh ! I am so dry,
Just moisten poor Jim's lips once more ; and, mother, do not cry."
With gentle, trembling haste, she held a teacup to his lips ;
He smiled to thank her ; then he took three tiny little sips,
"Tell father, when he comes from work, I said Good-night to him ;
And, mother, now I'll go to sleep." Alas ! poor little Jim,
She saw that he was dying—the child she loved so dear
Had utter'd the last words that she might ever hope to hear.
The cottage door was opened, the collier's step is heard ;
The father and the mother meet, but neither speak a word ;
He felt that all was over, he knew the child was dead ;
His quivering lip gives token of the grief he'd fain conceal ;
He took the candle in his hand, and walk'd towards the bed ;
And see the mother join him—the stricken couple kneel.
With hearts bow'd down with sadness, they humbly ask of Him,
In Heaven once more to meet their own poor little Jim.

IX.

SERMONS IN STONES.

IT appears that from the earliest times, as soon as man became civilised, he found the necessity of constructing for himself a somewhat firmer path than that with which Nature furnishes him. In such ancient cities as Athens, Rome, and Palmyra, we find the inhabitants were accustomed to cover the natural surface of the earth with some harder and more durable material, to serve as a pavement for vehicles and foot passengers. You are, of course, aware that in all towns in our own country this plan is followed, and is found to be an important essential. Anyone who looks for a moment at any of our important thoroughfares in London—the Strand or Cheapside, for instance—cannot avoid the conviction that if the only pavement in existence there was that which had been found to exist naturally in those particular spots, the highway would soon get in a terrible mess and full of ruts and holes, and the blocks which do sometimes occur even now in those crowded thoroughfares would occur very much more frequently, and would be much more serious when they happened.

Man, then, has always found it necessary, in using artificial material for paving purposes, to take advantage of those paving materials which Nature has supplied him with, and to transport them from certain places upon the earth's surface to those places where they are required. When the excavations were made at Pompeii and Herculaneum—those two cities which, you remember, were some 1800 years since buried and shut up—it was thought, doubtless, for ever, but modern science has unearthed them—it was found that the inhabitants of those old cities were in the habit of paving their streets with blocks of lava, obtained from the neighbouring mountain of Vesuvius, and we may take this as a matter of universal experience, for you will find in all towns that the pavements are made of materials which have been obtained from the nearest mountainous district.

If we take the ordinary paving materials in use in London we find that they consist of the so-called flags, or "sets," which are used for flagging the pavement, the granite kerbing, and also the granite rocks which are put down in the middle of the road for the passage of the heavier traffic of vehicles. As I have already said, you would doubtless think these were terribly uninteresting materials for a lecture, but I think, if each of those blocks of stone could only speak, they could tell not only the history of the countless myriads of sentient human beings who have passed over them, of their joys and sorrows, their good luck and their ill luck, but could tell a story of its own origin, of its history from its earliest time, that would make our very ears tingle with astonishment at the mighty secrets of Nature which it would unfold. This, of course, is out of the question; though there was a time when we are told that the paving-stones would have cried out, yet we never hear that they did.

This reminds me of a somewhat amusing story. Mark Twain tells us how he and some fellow-travellers were shown when they were in Jerusalem the stones that cried out when our Lord entered that city. "Oh," said one gentleman of the party, "but we don't read that the stones *did* cry out; we only read that the stones *would* have cried out if the children had not shouted Hosanna!" "Well," said the guide, quite unabashed, "these are the stones which would have cried out;" and so, with the usual veracity of guides, satisfied the party.

Seeing, then, that we have no means of extracting from paving-stones themselves any information by word of mouth, let us see if we cannot by examination of their structure, and the places from which they come, obtain some information as to their origin, and go as far back as we can in their history.

I am informed, and I believe correctly, that most of the materials which we use for paving in our principal towns come from some of the Welsh hills and from the Scotch mountains, and if we go to these native haunts of the stones used in our streets and hunt them in their native lair, perhaps we may learn something of their previous history. Let us go to Wales first. There we shall find several places from whence paving-stones are obtained; but as the names of these places are somewhat curious ones, and as I have a strong objection to dislocating my jaw, I am not going to attempt to pronounce them. I have been to most of them myself, and although I have greatly enjoyed what I have seen, and have obtained a great deal of information, I have never yet learnt how to pronounce their names. On paying a visit to any of these places we usually find a mountain or hill, such, for instance, as Snowdon—one of the few Christian names in Wales—rising above ground, which differs to a great extent from the character of the rocks forming there the crust of the earth, and you also find that these materials, of which the mountain-tops are formed, are such materials as the geologist tells us have been formed by the action of heat.

I know that the people in Drury-lane—and I am glad to find that it is so—are very suspicious of anything that appears very strange, owing, I suppose, to the remarkable statements scientific people occasionally make, so that they do not believe everything that is told them. Therefore, I do not wish you to accept my word only for the statement I have just made—viz., that most of the materials used in paving are such materials as could only have been formed by the action of heat. I will tell you a few reasons we have for supposing, or rather knowing, that these rocks were actually formed by such action.

If you go to certain parts of the earth—for instance, to the south of Italy, and other places in the south of Europe—you know, even at the present day, there are to be found a number of these curious phenomena known as volcanoes. In the *Messenger* for March, 1879, you will find, I think, a somewhat full account of these interesting phenomena, and if you refer to that account you will find that these volcanoes are constantly throwing up on to the surface of the earth a quantity of rocky material, part of which is in the shape of blocks of rock, some large, some small, part of it in the shape of very minute particles of volcanic dust, and then, in addition to this, most of them discharge vast floods of liquid rock, which is known as lava. Now, although the statement may appear somewhat strange, I may tell you that the blocks upon which you walked on your passage here this evening are mostly old lava streams. In this country, in Wales, and in Scotland especially, long ages ago, there existed volcanoes of precisely the same character, and of at least as great size, as those which we now find existing, happily for us, in distant parts of the globe; and if we examine the materials which are now being thrown out by so-called active volcanoes in other parts of the world, we find that those materials are getting cooled and hardened into rocks of the same character as those which can be found in our own country, especially in the northern parts of it. If you take a stream of lava, you find that as it starts from the mountain top it looks very fiery, especially if you see it by night; it then appears quite glowing. As you examine it farther down it becomes dimmer and dimmer, until at last you see what is apparently only a black stream of mud. Now, this appearance is caused in this way. The material which is thrown out of a volcano becomes cool very quickly, and very soon you get a crust formed upon the top of this stream coming from the mountain's top. When that crust is formed it is, as we say, a very bad conductor of heat—in other words, it does not allow the heat to pass through it very quickly; consequently it plays, with regard to the lava stream, just the same part as our great-coats do with us—that is to say, it keeps the heat in. Although above the surface the lava stream seems to consist of perfectly solid matter, with larger or smaller portions of solid rock, even for years after the origin of that stream, the undermost parts of it may be very hot, and for several months after they may be quite glowing. The consequence of this is that there is constantly arising from the undermost part a quantity of gas, just as is the case with a loaf of bread baked in an oven, the gas rising through the materials upon the top, makes a number of holes, and if you look at the surface of a lava stream you will find that the rock there is perforated by large numbers of holes; in fact, it is pumice-stone. Underneath you will find a great many cracks, and fissures, and grooves, and sometimes you will find a number of columns of this lava which, when excavated, have a very beautiful appearance. We know, of course, that these materials have a definite composition; for instance, we find a rock called basalt, and several other rocks of a similar kind, which have a definite character, position, and appearance.

Having, we will suppose, been to an active volcano and examined carefully what Nature is doing to-day in that region, let us go back again to Wales or to Scotland, or some other part of our island from whence paving-stones come, and we shall find that in these places we have just the same conditions as we find in those parts of the earth where volcanic action is now going on. You have heard, no doubt, of the Isle of Staffa. In that island we have a magnificent example of what Nature can do in some of her fiercest moods, when she displays her giant energy. We find that that island is wholly a product of volcanic action, and just in the same way we find that the structure of the lava stream is similar to that made to-day. As we find that the undermost portion of these streams sometimes assumes a columnar shape, so you find here that a number of immense columns of basalt have been built up by the fairy hand of Nature, into what looks something like a magnificent temple in which man himself might with advantage worship; for here is a temple reared by Nature's own hands, in which the devout may worship Nature's God. These columns are of basalt, the same material which we find in the volcanic rocks of the present day.

In many other parts of the British Islands we find that we have remains of ancient lava streams, and the material obtained here is one of the most useful and important used for paving. As a general rule, we find that there are three materials present in our paving stones, whether it be kerbstones or flags. The materials in granite, which is a typical rock, are quartz, a mineral known as felspar, and certain glistening metallic particles which are mica. If you take up a piece of granite when the road is being mended, you will find that it consists of the three materials I have mentioned. You will find, also, that these materials are not arranged in any definite order, but are simply indiscriminately scattered throughout the mass. Pull out your spectacles if you have a pair, and look at the rock carefully, and you will see not only that these materials are scattered indiscriminately through the mass, but that none of them are at all rounded; they are all sharp and angular. That is just the character of the rocks which are being formed in the present day by the action of heat.

Another material is known as "syenite," and of that material most of the Welsh hills are formed. Granite comes mainly from such old Scotch friends as Ben Nevis, Ben MacDhui, and two or three others. Now, this syenite is so named because near a place called Syené, in Egypt, large quantities of it are found. It is just like granite, except that the mica is replaced by another material known as horn-blende. I want to take granite, or syenite, it does not matter much, for a few minutes, and look at its origin specially. Not only were these rocks formed by heat, but they were formed at a very great depth beneath the present surface of the earth. How they came to be upheaved so far above the surface we will presently inquire.

There can be little doubt that such rocks as granite and syenite, the two I have mentioned, were at one time deposited beneath the bottom of the ocean. Long back in the ages, farther than ever we can count, these rocks were deposited at the bottom of the ocean, and since then they have been submitted to enormous pressure, buried fathoms deep beneath the surface of the earth. There they have been served very much as your meat and potatoes are served when you take them to the bakehouse—they have been baked. Granite and syenite are simply baked rock. The interior of the earth is, as I suppose every one knows, very much warmer than the surface; and the farther you go down, so far as we have been able to penetrate, the hotter it gets. For about every 60 feet you go down the temperature rises about 1 degree. This holds good, with slight variations, all over the world. Beneath the surface of the earth these rocks have been so altered by this baking process consequent upon the great heat, that their character has been altogether altered. They are entirely different in appearance from such rocks as we at present know to be formed by the action of water. These metamorphosed rocks have been subsequently upheaved, so that the tops of the loftiest mountains in the world are at present formed of them.

How has all this come about? To answer this question we must fall back upon the same agent to which I just now referred. Heat is at the bottom of the business everywhere. Heat has not only been the great prime mover of the various changes which have taken place in the past history of the world, but it is the great prime mover now. Not a floweret that blooms in the woodlands, not a man that breathes, not an animal that lives for the service of man, not a steam-engine that traverses our railroads, but owes its origin to this motive power. The sun is the great prime mover of the universe; the very coals we burn to keep us warm and to cook our food are only "bottled up" sunshine—sunshine which long ages ago fell upon forests where no man or woman ever breathed, which have since been buried beneath the earth and converted into coal. Just the same thing is true of the upheaval of these huge mountains, which at one time must have been buried many thousand feet beneath the surface of the earth.

Volcanoes and earthquakes are, as you know, at present constantly startling us by their presence and action. Only a few weeks ago the thrilling news of a terrible earthquake in the Ægean Sea reached us, by which it is calculated that from 4000 to 5000 persons have lost their lives, and 40,000 to 50,000 people rendered homeless; and as we contemplate these great phenomena, these indications of Nature's power, we are sometimes inclined to feel a little bit displeased at the Providence which has ordered them, and inclined to ask whether it is true that that Providence is quite a beneficent one; but when we come to consider even the history of paving-stones, we find that the tremendous agency which seems to shake the earth to its very foundations is simply one phase of the activity which has resulted in the present form of the surface of the earth, and without which, probably, neither you nor I could have existed upon this planet.

As the imprisoned heat beneath the earth's surface is constantly tending to make its way towards the surface—constantly trying to burst its rocky prison, it strains and stretches the rocks, which form the earth's crust, and occasionally it pushes them upwards with violent force, but more often it gradually upheaves them. Again, you say, how do I know that? If you go into certain parts of the country—and there are numerous places where you may see these phenomena—you will find that the rocks, which have been in the first instance deposited in layers, one upon another, just like a pile of books, seem to have been tumbled over. Sometimes you will find that the layers of rock, instead of lying quite horizontal, have been simply turned up, sometimes they will stand quite on their end, very much, in fact, like books upon a bookshelf. Then, again, you will find, in many cases, that besides being thus tilted out of their natural position, they have been crumpled up. I could show you one very good instance of that, near Weymouth. This fact was beautifully explained by the geologist, Forbes, some years ago. You know if you place a number of pieces of cloth on each other, and then place a heavy weight on the top, and apply pressure, the result will be that the pieces of cloth are thrown into a series of wave-like curves. The position of those pieces of cloth under the conditions which I have named is precisely that which we have in these layers of rock, and there is every reason to believe that such were the conditions under which these rocks were thus twisted and contorted. The heavy pressure of the rocks upon the top, and the pressure also at the sides, together with the straining of other material to get near the surface, have thrown these rocks into the wave-like curves I have referred to, and in some cases they have been so twisted, so deformed, and altered from their natural position, that, as Mr Weller said, "their most formiliar friend wouldn't know 'em."

This is what happens in many parts of our own country, and if you take the whole world, I am quite within the mark in saying that there are many thousands of such instances. They can be found without the least trouble ; in fact, it is quite the exception and by no means the rule to find the layers of rock arranged in their natural horizontal position. That, you say, is a strange thing; but, stop, my friends! Do not let us be in a hurry. Nature has an object in everything she does, and the object in throwing these rocks on their sides, turning them up on end, and twisting them about, is not to make Nature appear a curious and somewhat interesting phenomenon. It was for something far higher that these rocks were twisted and turned about. It was for that purpose for which the animals were created—for the service of man. If it had not been for this turning and upheaving process, the turning of the different layers of rock on their ends especially, many of the materials which you and I have occasion to use every day of our lives—iron, coal, and various kinds of stones—would have laid for ever buried far deeper down in the earth than man could ever have reached; he could never have known of them, nor had the benefit of them. Even in this arrangement, which seems at first sight to be merely a freak of Nature, we have an example of that ever-watchful care, which has so rightly been named Providence, which goes before to provide for us His unworthy children.

The paving-stones, I said, were baked. Some of the material which we use in the paving of our streets has also baked other rocks. You know that at all times, when the earth is in the throes of those convulsions of Nature which we call earthquakes and volcanoes, the straining and stretching of the earth's crust produces beneath the surface a number of fissures and clefts, and, as the heated material endeavours to force its way to the surface, some of it is forced in a hot liquid condition into these clefts, and there it remains. Again, let me give you a reason. I said that the material was forced through the overlying rock in a highly heated condition. How do I know that? If you had your chimney on fire you would have a very reasonable right to say that the fire burnt it; and although you may not have seen the fire, or the oven that baked your Sunday's dinner, you know very well that heat must have been the agency employed to cause the materials of your dinner to assume their present condition. Now, when I look at a series of rocks, "in the field," as we say—in their natural position—and I find that there is a mass of rock sticking up, let us say, in a bed of coal, and when I find that on each side of that piece of rock we have soot, a little further away cinders, and a little further away still smokeless coal—anthracite—I think you will admit that I am perfectly justified in saying that when this interposing mass of rock was sent through the coal, it was very hot, because you see the coal in contact with it has been converted into soot, a little farther on it has been baked, and altered, as we see, into cinders, or blind, smokeless, anthracite coal. So, you see, here again the paving-stones would have a wonderful history to tell us of what has taken place beneath the surface of the earth. If you take a circle drawn upon the blackboard to represent the earth, the mark of the chalk is rather too thick to represent upon that scale the amount of the earth's crust that man knows anything about, and this material which we are every day treading beneath our feet would, if it could only speak, tell us something we are all anxious to know about—viz., the condition of the earth thousands of feet below the surface.

Having gone so far as to assume what is evidently true, that somewhere beneath the earth's surface there is a great amount of heated material, you naturally ask, How is it that the earth itself does not feel hot at the surface? You know that many of our friends in the neighbourhood are in the habit of running about without troubling the shoemaker for any covering for their feet, and they sometimes, poor creatures, find it wretchedly cold; and we know ourselves that although in the summer, if we walk on the ground, we do not feel any particular chill, and we may find it warm, we never find it very hot, or not so hot as we at first might suppose it to be, considering that the interior of the earth is probably composed of liquid and gaseous material in a highly heated condition. The answer to that natural question is given us by our lava stream. The stream of lava, I told you, was covered with a crust which is a very bad conductor of heat, and that although you might walk upon it barefooted without suffering inconvenience, you have only just to penetrate a little beneath the surface to come upon a very great heat. Just the same thing is the case with the earth. The crust of the earth is made up of materials which do not allow the heat to pass readily through them; consequently, although there is undoubtedly a considerable store of heat not a very great way beneath the surface, that heat is unable to penetrate to the surface or in any way to appreciably affect its temperature.

Having said so much about paving-stones, you may be inclined to ask what relation they have to the other stones which we so frequently make use of—for instance, what relation have they to the stones which are used in some places for making roads—the so-called "cobble" stones; and then, again, what relation have all these to the stones which are used for building purposes? If your patience is not altogether exhausted, I will try to give you a little information upon this head also. As to cobble stones, many of you who know any of our provincial towns will have a very good knowledge of them. The roads there are paved with these stones, which have a smooth rounded surface, and are firmly imbedded in the subsoil closely side by side, so as to form a durable and useful paving. In some parts of the north of England you will find a lot of these stones scattered about, and very often imbedded in clay. Sometimes the clay completely hides them, and you have to remove a small thickness of it before you come to the stones. If you then examine these stones you will find that they are not at all of the same character as any rocks in the neighbourhood. If you examine them more closely still you will find that the granite, or whatever material it may be which lies there, has evidently come from a distance. They are very much scrubbed and scraped, as though they had undergone such a scrubbing as that "Dirty Boy" whom we see so often in the shop-windows is undergoing. These stones have been scratched and scraped so hardly that we observe upon them grooves, stripes, and furrows. These are the stones which are so largely used in some of our provincial towns for paving the roads, and every one of those stripes and grooves upon them has a story to tell—how it was produced by the action of ice.

I said something in a former lecture on this part of my subject, so I will just remind you of how these stones got in their present position. Some long time ago, probably about 200,000 years, this country and the north of Europe was covered with an immense cap of ice, similar to that which now exists in Greenland, and that ice, as it is now in Greenland, was in a state of motion, in the form of glaciers, or rivers of ice, travelling to the mountains' foot. Pieces of that ice then broke off, and floated away upon the sea, beneath which at that time nearly all Europe lay buried. Presently the climate got warmer, and one by one, little by little, these great icebergs melted; and, as they melted, the stones which had fallen on the top of them, or which had been imbedded in them, and which had been scraped off from the sides of mountains and valleys through which they travelled, were deposited at the bottom of that ocean; and then, slowly, the land rose and shook off its dripping mantle and became dry ground, and there, imbedded in the clay which was deposited during the latter part of this period, and sometimes covered over by it, we find at the present day stones which must have travelled from the mountains of Scotland down to the midland counties of England. These are the stones which generations of feet have passed over, and very few of the individuals who travel across them have the least idea of the wondrous history each one of these stones could tell.

Now as to building stones. Building stones differ from the stones ordinarily used for paving, inasmuch as they are formed not directly by the action of heat, but by the action of water. How do we know that these stones are formed by the action of water? If you take any one of these stones, say a piece of sandstone, you will find just the same materials in it as you find in the piece of granite; you find quartz, felspar, and mica, but those materials are arranged in a definite order, not indiscriminately scattered through the mass. They are arranged in layers, little tiny layers, one upon another, and you will find, if you visit a stone-quarry, that of these smaller layers several have been packed into one big layer, and so the layers of stone rise one above another in a quarry, almost as regularly as the stones do in a finished building.

Moreover, if you take your spectacles out again, and look at the piece of sandstone, you will find that, unlike the piece of granite, its particles are all beautifully smoothed and rounded, and from the condition of these particles, as we shall presently show you, we have reason to know that water is the only agency which could have produced such a condition of things. Moreover, in our examination of rocks such as sandstone we find, very often, ripple marks in them —marks, that is to say, left by waves as they gently rippled on the beaches of long ago. Then, too, we find in some places little holes which have evidently been made by the rain, and so we have rain-drops whose marks have been preserved through many long ages, teaching us a lesson how insignificant objects may leave an impression which shall far outlast that left by some of the greatest agencies which man or Nature could furnish. Then, last, but by no means least, we find in many of these sandstones the remains of animal and vegetable life, which flourished upon the surface of the earth at an indefinitely remote period.

If I were to take you to a piece of ground and you were to make an excavation there, and you found as you got down a number of shells of such animals as mussels, winkles, and creatures of that sort, I do not think I should require to use very much persuasion to convince you that they must have lived beneath the sea, and that, therefore, the place undergoing examination must at one time have formed the bottom of the sea. Well, now, when we come to examine the sandstone, and limestone, and materials of that kind, we find that they too yield us the remains of animals such as I have mentioned; and which we know from experience could not possibly have lived in any but sea-water, and could not possibly have breathed upon land. We find, moreover, that these rocks have exactly the same character as the sand which exists upon our sea-shores at the present day.

As you see a mighty river flowing along, just gently meandering to the sea, perhaps upon some calm summer's day, when scarcely a ripple disturbs its surface, it seems to you the embodiment of all that is peaceful and quiet, just simply strolling along, as it were, on a pleasant journey to the sea. Although the surface of that river looks so quiet, beneath its surface there is going on an amount of work of which you, perhaps, have little notion. Let us go back to the hills from whence the river came, and what do we find there? We find dashing down some mountain side a little busy torrent, and as it dashes down it carries along a number of small pieces of stone, which have been chipped off or which have fallen off from the mountain's side. Take up some of these pieces of rock, and you will find that they are simply sharp, jagged, angular fragments. Following the stream downward, you will find that as you go along you will have a turbid stream for some time. You can hear those stones being dashed together as it rushes along, bearing them with it. As you get down lower, take up some of the fragments again, and you will find that instead of having rough irregular edges they are beautifully rounded, and as you get lower down still you have those beautifully polished and rounded pebbles with which we are so familiar, with not a sharp edge upon their surface.

Besides all these round pebbles, of course, you must naturally have smaller fragments, and dust which has been worn off from the angles in this rounding and polishing process, and so you will find that the stream in its upper parts, as it sweeps along, is carrying with it a quantity of fine sand or sediment, and that it is pushing along its bed a quantity of larger material, pebbles and so forth. If you are in a boat, on some quiet summer's day, upon the surface of some broad river just before it gets to the sea, and you listen intently, you will hear the sound of the grand anthem which the river sings as it drives down to the sea hundreds of thousands of tons of this sediment, which it is gradually pushing towards the ocean to form a portion of that ocean's floor.

As you get nearer to the sea you know that the speed of the river gradually gets less and less; and you know, perhaps, that the carrying power of water depends very largely upon its speed. You can easily prove that for yourselves. Supposing we have three glasses, into which we put water. Into the first we put some pebbles, coarse sand in another, and very fine sand in the third. Now, shake up the fine sand, and you will find that it is a very long time before it settles down, the motion of the water enabling it to carry in suspension, as we say, a quantity of the sand, such motion being sufficient to carry the sand any distance so long as it is kept up. If you shake up the coarse sand you will find that for a short time also that can be held in suspension by the water, but it sinks much more rapidly to the bottom of the glass than did the fine sand. Then, finally, upon shaking up the gravel and stones, you will find that they sink immediately, even if they rise at all. Immense masses of water, however, pushing their way downwards towards the sea, though they could not carry large stones, could push them along the bed of the river.

Going back to the river—as you get to the estuary, or mouth of the river,' it meets there the mass of water in the ocean, which imposes a check upon the motion of the river water, which check causes it to deposit the larger part of this sediment. Thus it is that most rivers have a bar at their mouths, which bar is, as you know, a very great inconvenience to ships, because, when the tide is low, there is not sufficient water over the bar to carry the vessel, and therefore they are obliged to wait until high water to enable them to get over it. Just at the mouth of the river you have an immense deposit of sand; a little farther out a finer sediment—the finer the sediment the farther it will be carried out, and you will have a kind of tongue-shaped mass reaching out from the mouth of the river to a great distance into the sea.

Imagine this process going on, as it certainly has been, century after century, age after age; just call to mind the enormous quantities of sediment which must thus be carried down to the sea, and you will easily see that the pressure to which the lowermost masses of sand are subjected will be something enormous—in fact, sufficiently great to drive the particles so closely together as to cause them to cohere and form a solid mass. That this is possible you can easily prove by submitting masses of sand to powerful hydraulic pressure, as it is thus converted into solid rock: much more, then, will the giant forces of Nature, exerting themselves through long ages of time, consolidate the loose sand, gravel, and mud into solid rock; and just in that way we have every reason to believe the sandstone we use in building has been formed.

Other kinds of rock have been formed by the action of animals. Animal remains, as you probably know, form at the present day a large portion of the rocky deposit going on beneath the existing ocean; and just in the same way enormous masses of rock, which now form part of the dry land, were in ages past formed by the work of successive generations of minute animals. Thus even from the stones which form the walls of our dwellings we may extract some instruction, and you see that though walls have ears, they have also tongues, and if we only listen aright we may learn something of their history from them.

My time has gone. I can only thank you for listening so kindly and attentively to what is, perhaps, a somewhat dry subject; but you see that it does not matter where we turn in Nature, there is evidence of a Providence constantly exerting itself for the benefit of man. Not only do we enjoy the enormous blessings of air, light, and sunshine, which can be enjoyed alike by the naked savage and the lady in her drawing-room, by the peasant in his cot and the prince in his palace; but, more than that, God has provided even for the wants of our civilisation. Providence has endowed man with the power to make nature serve him, by extracting from her storehouse materials which are useful even for the highest purposes of our race, and, moreover, as we have seen, preaches to him, "sermons in stones."

X.

HOW THE EARTH IS WEIGHED AND MEASURED.

AMONGST the numerous triumphs of modern science few have been more brilliant or more complete than the discovery of those methods by which, on the one hand, man has been enabled to weigh the almost infinitely minute, and on the other the almost infinitely vast. While the chemist and the physicist have weighed atoms and molecules—particles so minute as to be, at present, far beyond the reach of the most powerful microscope, the astronomer has put suns and planets in the balance, and has meted out the heavens with a span. As a general rule it is commonly supposed that the methods which have been adopted to arrive at these results are very profound, and so intricate as to be far beyond the reach of the ordinary understanding, and the results have been accepted with an unquestioning faith, which, while it speaks highly for the confidence with which the scientist has inspired his fellow-men, is totally at variance with the scientific spirit. It will, therefore, be my endeavour in this lecture to show you that, in one direction at least, these methods may be understood by persons of ordinary intelligence, and possessed of only elementary education. I have selected the weighing and measuring of the earth, not only because the results are necessarily the most interesting to the dwellers upon our planet, but also because the methods which have been adopted are very closely allied with those which the astronomer has extended to the more distant realms of space.

About 200 years ago Sir Isaac Newton startled the scientific world by the announcement of a new discovery—a discovery which has since been so abundantly verified, that it has long since been removed from the region of mere theory or hypothesis, and has acquired the *status* of a natural law. This law is known as the law of gravitation; and if you will allow me, I will first of all tell you what it is in scientific language, and explain it afterwards. The law of gravitation is this: every particle of matter in the universe exercises upon every other particle an attraction which is called the force of gravitation. This force is directly proportional to the mass of the bodies concerned, and inversely proportional to the square of their distance. Let us try and put that into ordinary language. Every particle of matter in the universe, no matter how vast or how minute, exercises upon every other particle an attraction; that is to say, draws every other particle of matter in the universe towards itself. This attraction, we are told, varies directly as the mass of the bodies concerned. Now "mass" means weight, and I can explain this part of the law of gravitation best by saying that if you had two bodies, one weighing 2lb. and the other 1lb., other things being equal, the attraction exercised by the 2lb. body would be twice as much as the attraction exercised by the body weighing 1lb. Then we are told, finally, that the force of gravitation varies inversely as the square of the distance. "Inversely" means—as applied to husband and wife, "perversely"—in an opposite direction; as one decreases, the other increases. You know that the farther you get off from a light the dimmer the light appears; that is to say, as your distance from the light increases, the light decreases. So is it with the force of gravitation. If you have two bodies, one, say, two miles away from the earth, and the other one, the body two miles off will be attracted by the earth with less force than the one which is nearer, and which is only one mile off. The proportional attraction will not, however, be simply as one to two, but as one to four; that is to say, the body distant one mile will be attracted with four times the force exercised upon that at two miles distance, or, in other words, double the distance you divide the force by four; halve the distance, and you multiply the force by four. This is what in science is called the law of inverse squares, the square of a number being that number multiplied by itself.

This is, in simple language, the great law of gravitation, and I have laid such stress upon it for this reason—it is by the application of this law of gravitation that the earth has been weighed and measured. In order that you may fully understand—for I want to make you do so, if I can—how this wonderful process has been effected, I must ask you to allow me to define certain terms which I shall be obliged to use, which are not very new, but which, perhaps, have not been so thoroughly understood by all of us as they ought to have been. First of all, what do we mean by the "volume of a body"? The volume of a body is its size—in other words, the amount of space which it occupies, and which, of course, can be ascertained simply by measurement. This black board, for instance, I measure in length, in width, and in thickness, and by multiplying the figures representing these three measurements together, I know exactly how big it is, what space it occupies—in other words, its volume.

Then, again, we all fancy we know exactly what is meant by weight. Do we know what is meant by the weight of a body? You know in the Court of Exchequer there is kept a certain piece of platinum, which is called the "standard pound weight." Now, that piece of platinum is pulled downwards—attracted, that is, by the earth, and is attracted with a certain force, which we call a pound for the sake of convenience, and we agree to call every other mass of matter which is pulled down with an equal force a pound, whether it be composed of butter, cheese, bacon, or anything else;

and so you see, the pound weight owes its special property to the attraction of the earth for it. If the earth had no attraction for the pound weight of iron or platinum, and the weight no attraction for the earth, it would cease to have any weight, and if in any way the amount of the earth's attraction for bodies upon its surface were to vary, our pound weight would have to be altered in size. If we understand that clearly, I think we shall be able to get through our problem with very little trouble to ourselves, but it is necessary that we must have a clear notion that a pound weight simply *is* a pound weight because the earth attracts it, and it attracts the earth. We must not forget that the attraction is a reciprocal one; that is to say, that it acts in both directions. In my hand I hold a piece of chalk; you know, if I let it drop it will fall towards the earth. Why does it fall towards the earth? Because the earth attracts it. But you must not forget that not only does the earth attract the piece of chalk, but the piece of chalk attracts the earth, only the piece of chalk being almost infinitely small as compared with the earth, it is easy and convenient to consider that the attraction is only in one direction, that it is only the attraction of the earth upon the piece of chalk.

Now, besides the ordinary weights such as we speak of in the ordinary business of life, we have for a certain special purpose what are known as special weights, or "specific gravities," as scientific men call them. It is found convenient to have some means of registering the comparative weights of different substances. You know, of course, that if you have a piece of iron a foot square, or, rather, a foot cube, and if you have another cubic foot of lead, a cubic foot of glass, and a cubic foot of wood—masses of matter, that is, of precisely the same size—they do not all weigh alike. Every one knows that the lead would be heaviest, that the iron would be heavier than the glass or even the wood. Now, it is found very convenient to have some means of always expressing these proportionate weights of different kinds of material, and these specific weights are called by the scientist specific gravities. One substance is taken as the standard for comparison, and with that standard substance every other body is compared. The substance usually taken is water. We take, for instance, a cubic foot of water, and weigh against it a cubic foot of iron, a cubic foot of lead, of gold—anything we like, and we find how many times heavier the wood, iron, lead, or gold is than the cubic foot of water. We find, for instance, that a cubic foot of iron is seven and a half times as heavy asa cubic foot of water; and so we say that the specific gravity of iron is 7½; a cubic foot of gold, we find, is nineteen times as heavy as a cubic foot of water, and we say that gold has a specific gravity of 19, and so on.

If I wanted to get the weight of some very large body, say an iron girder, which it would not be convenient to put in a pair of scales, or upon a weighing machine, I need not be baffled by the problem; it is quite easy to do it without putting it on the scale at all. If I measure the girder—its length, breadth, and thickness—and multiply the figure representing these together, I shall find out how many feet there are in it. I say to myself there are a hundred feet of iron in this girder; now I know what one cubic foot of water weighs—a thousand ounces—and, therefore, if this girder were made of water instead of iron, it would obviously weigh 100,000 ounces. But I know that iron is seven and a half times heavier than water, and, therefore, this girder must weigh seven and a half times 100,000 ounces. We have not, perhaps, all passed the Sixth Standard, but still I think we all can do such a simple sum as that; seven and a half times 100,000 ounces gives us 750,000 ounces as the accurate weight of our girder. We should know that just as well as if we had put it in the scale and weighed it. Of course if we want it expressed in tons, hundredweights, and quarters, we have only to do a simple reduction sum, which is not very difficult. I want you to see this point very clearly, because it is the cardinal point upon which all the rest turns. To weigh a body you need not necessarily put it in the scale, if you only know how much heavier the substance to be weighed is, bulk for bulk, than water; you can simply by measuring it find out its exact weight; without that, of course, the problem of weighing the earth seems one very improbable of solution.

You may recollect that Archimedes, the old Greek philosopher, once said that he could move the earth with a lever if he could only find some place for his fulcrum—*i.e.*, the point to rest the lever upon. Of course, he could not find that point outside the earth, and therefore the idea of moving the earth was purely imaginary. Just in the same way, we know that if we had to put the earth in scales, the solution of our problem would be impossible; but as it is not necessary to put a thing in scales if you can only find out its size and its specific gravity or density, we can see that if we can only find out how much more a cubic foot of the earth weighs than a cubic foot of water, we shall find that our problem resolves itself into this: find out the density of the earth—how much heavier a cubic foot of earth is than a cubic foot of water.

About a hundred years ago certain scientific men thought they saw their way clear to solve this problem, and the way they set to work was this. They said, "We know that the earth attracts bodies upon its surface, and we know that not merely the earth as a whole, but every particle of matter in the earth, exercises this attraction upon the bodies at the surface." You know it is not uncommon for people whose information is not very accurate, and for bad scientific text-books, which ought long ago to have been burned by the common hangman—it is customary for these people and books to say that the reason why a stone falls to the ground when it is let go is that the earth's centre attracts it. Now that is very beautiful, perhaps, but it is not true, because the law of gravitation is, that every particle of matter in the earth must exercise upon the stone a perfectly separate and independent attraction. "Therefore," said the philosopher, "some parts of the earth, at the other side, for instance, are at least 8000 miles away, and therefore they must exercise a very small amount of attraction upon the bodies on the surface. If we take some large body, such as a mountain, on the surface of the earth, we might find that although that mountain, as compared with the earth, is very small, on account of its being so very near, its attraction may counteract the attraction of the earth." This was the principle upon which they set to work, and the experiment which they performed was this.

You all know what a plumb-line is, which a bricklayer uses to square his walls with; in point of fact, it is nothing less than a string with a weight at the end, and the properties of the plumb-line are that, when it is suspended freely, it hangs in a perfectly vertical line, pointing downwards to the earth's centre. What makes it do that? Obviously the attraction which the earth has for the weight at the end of the line; that attraction holds it in that particular position. Now, if you hold your plumb-line by the side of a mountain you will find this is what happens: the mountain pulls it out of the straight line, and the experiment which was carried on at the end of the last century consisted in taking a plumb-line to a mountain in Perthshire, called Schehallien, and in observing how much the mountain pulled on one side the plumb-line. Two stations were taken, one on one side of the mountain and one on the other. The plumb-line was observed at one station and then at the other, and it was found that the plumb-line was at each station pulled towards the mountain, and that this pulling of the line towards the mountain produced, of course, an angle between the two directions at the two different places. The problem now simply resolves itself into this—we find that the plumb-line at these two stations is pulled on one side by the mountain to a certain extent. If we can find out how much the mountain weighs—we know how much attraction the mountain exercises upon the plumb-line—and from that we can find out how much the weight of the whole earth must be to cause the plumb-line to hang in the position which it does. So you see the problem to be solved now was simply to find out how much the mountain weighed, and then, knowing the effect of that weight upon the plumb-line, to find out what must be the weight of the entire earth to cause the plumb-line to assume its vertical position.

This was done by surveying and measuring the mountain with the utmost care, with all the means and appliances which the science of the day could possibly bring to bear on the subject. Every plan known was brought into play, so as to ensure the most perfect accuracy. They measured the mountain, they calculated its volume, and then they set to work to find out what was its specific gravity—its density—to find out, that is, what was the weight of the rocks of which the mountain was made up, and their weight as compared with the same quantity of water, bulk for bulk. The result of their weighing was then found to be that the mountain must be, bulk for bulk, much lighter than the whole body of the earth, and from that they concluded that the earth must weigh about five times as much as it would if it were composed entirely of water, and that was the result of the experiment.

Now, we see that they obtained their result as I assumed we got the weight of the iron girder; they found out the density, or specific gravity, of the earth, and they had only to find out its size and the problem was solved. You know that in science it is necessary to be very careful; it is necessary not only that you should do your sum, but that you should prove it. Unless a scientific man proves his sum when he has done it, the result is not worth much; consequently, various ways have been invented for checking this result which was obtained by the experiment on the mountain. Not satisfied at the result obtained by the Schehallien experiment, as it is called, a Mr Cavendish, a man who was not only very wealthy, but had an extreme love for science, devised another way of finding out the weight of the earth. I will not trouble you with an explanation of his method, but will simply give you just an outline of the process. A wooden rod had two small balls attached to it, one at each end, and it was delicately suspended by a single silver wire. Near to the small balls at the end of the rod two large balls of lead were brought, and it was found by very careful observation that these balls of lead actually attracted the small balls at the end of the rod and twisted the wire. By a very careful and accurate observation of the exact amount of attraction and the known weight of these balls, the weight of the whole earth was by this means ascertained, and it was found by this experiment to be a little more than that which the Schehallien experiment had shown. It was by this experiment determined that the weight of the earth is rather more than five and a half times as great as the weight of a globe of water the same size.

Some of you know, I dare say, of the parson—of course he was an Irishman, as all stories which are particularly witty are attributed to Irishmen—who observed one Sunday that his congregation were getting very sleepy, and evidently very tired of his sermon; so he said—"My friends, I am exactly half through my sermon, but the next half is not so long as the one you have heard." Now I am at least half through my lecture, and you have heard by far the hardest part of it; the next part is very much easier. Understanding that we have found out that our earth weighs five and a half times as much as a globe of water the same size, we have only to get the measurement of the earth and our problem is solved. How shall we measure it? I think we can make that clear to you by first of all referring you to the way in which places are found and distances measured upon the earth's surface. If I make a small dot with the chalk upon the surface of the blackboard, I think you will see that if I wanted you to find its exact position on the board, I must give you, at least, two measurements; it would be no use my saying that it was, say, 30 inches from the bottom of the board, because if we drew a line across the board 30 inches from the bottom, that spot might be anywhere upon that line, and still it would be 30 inches from the bottom. Or, I might say that it was 18 inches from the side; but, again, if I were to draw a line down the board 18 inches from the side that spot might be upon any part of that line and still be 18 inches from the side; but if I told you that it is 30 inches from the bottom and 18 inches from the side of the board, then you know that you could find the spot, because it would be where the two lines cut one another, and by thus giving you two measurements, I can at once point out to you with the greatest accuracy the exact position of the spot upon the blackboard; but if you think the matter over, you will see very clearly that I could not give you its exact position without I gave you at least two measurements; one is not sufficient.

Just in the same way, if you want to tell a sailor where to find a certain spot upon the earth's surface, you must give him two measurements; one is not sufficient. The earth, as you know, is divided into two parts by an imaginary line going round the middle, called the Equator, and it is usual to reckon distances on either side of the Equator, north or south, and we speak of these distances as *latitudes;* the sailor is either in north or south latitude, and distances being measured by degrees, he says he is so many degrees north or south latitude, meaning thereby that he is so many degrees north or south of the Equator. But you see if he only speaks of latitude he simply speaks of distance north or south of the Equator. He says, for instance, that he is in 30° north latitude; he says in that expression, that he is somewhere about what we call the 30th parallel of latitude; but if any one started out with the intention of finding him, such a person might, of course, go all round the earth before he found him, because the person he sought might be anywhere upon that parallel of latitude 30° north of the Equator.

Sailors, however, in measuring distances use another term, which they call longitude. And longitude means the distance east or west of some place taken as a starting point. Most countries reckon from Greenwich. We call Greenwich our starting point; we measure degrees east or west of Greenwich, and we call them meridians of longitude. If a sailor says he is 15° west of Greenwich—in other words, if his longitude is 15° and his latitude 30°, then we are able to fix upon the map, or upon the globe, the exact spot which that sailor intends to indicate; and so you see, by two measurements, and not less than two, the sailor, or any one else, can fix his exact position upon the earth's surface, or can indicate the exact position of any place upon the globe about which he wishes to speak. I hope this is clear, because the clear is the true, and if we can only make a thing clear, we may be tolerably sure that we have got hold of the truth.

Now then, you say, how is it that you find out this latitude and longitude? A man goes to sea, and he has no landmarks to go by; you cannot say to a sailor that a certain island is next to something else, as you might tell any one else that a certain house in the Strand was next to the "King," or "Queen," or "Red-Bear," or some other equally curious zoological specimen. If, however, he has no landmark to go by, he has heaven-marks—the stars, the sun, and the moon. First of all, how does the sailor find his latitude? Now, as we stand upon the earth, over us is the beautiful blue vault which on a clear night is studded with stars. We might represent it as a semicircle, and thus the globe would be simply a small sphere, inside a large one, and we can easily understand how the old Greeks used to fancy that the stars were set in a crystal sphere which constantly revolved. We know better; we know that it is we that are moving, and not the fixed stars. Nevertheless, the effect is just the same. We have, as I have said before, a circle round the globe which we call the Equator, and we can see that by extending that to the heavens we shall have a celestial Equator, as we have a terrestrial one; by extending poles to the sky, we shall have poles in the heavens as well as upon the earth. Supposing a sailor wants to find out his latitude, in other words, his distance from the Equator, this is what he does. Certain bright stars are well known to him; he knows exactly how far off they are from the North or South Pole, as the case may be; he turns his telescope to a star which he knows to be 10° from the north or south, but he finds out that that star is 30° away from the point exactly over his head; that is to say, 30° away from him; thirty and ten are forty, he knows that he is 40° from the North Pole. Now the distance from the Equator to the North Pole is 90°, and forty from ninety, as any boy in the First Standard will tell you, leaves fifty, and therefore the sailor knows that he is in 50° north latitude by such an observation as the one I have supposed. So you see, finding your latitude is simply noticing your distance from certain stars, the position of which is well known.

To make the matter quite clear to you, suppose you are travelling across country, and you know your home is somewhere near, and you get on the top of the first hill you come to and look round. You see the steeple of your church, say, down to the right, and it looks about two miles away. "I want to go two miles the other side of that," you say, "consequently I am four miles away from my journey's end." That is taking your latitude upon a small scale, just in the same way as the sailor takes his latitude by looking at certain well-known stars.

So far, so good; but how does the sailor find out his longitude? That is a matter simply of knowing the time. Everybody knows that the earth turns round once in twenty-four hours upon its axis, and that it is this daily revolution which causes day and night. We know, too, that the earth turns from west to east, and, therefore, that the sun seems to go from east to west, and we know that just at the time when we are thinking of going to bed, the people in Australia are just about thinking of getting up—that is to say, that when it is day with us it is night with them, and *vice versâ*. We know, also, that every place upon the earth has a different local time; that 12 o'clock, for instance, in Paris, is earlier than it is 12 o'clock in London. If you start from London to go to America, you will find that your watch—very good timekeeper though it may be—will gain tremendously, so that you will very soon find it is an hour or so fast. In point of fact, the watch has not gained at all; you have been trying to race the sun, and to a certain extent you have succeeded. If you were to start from Greenwich to sail round the world in a westerly direction, when you got home again you would find that you had gained a day; you would find that you had had one day more than the people who had stopped at home. That which makes night and day is the turning round of the earth on its axis, and if you start in the same direction and go once round you have been round once more than the earth, and so you have gained a day. If you go round in the opposite direction you lose a day. That shows us this—in twenty-four hours the earth goes completely round once, and the earth's surface is divided into 360°. There are twenty-four hours in a day, and twenty-four into 360—you can ask Johnny when he comes home from school—is fifteen—*i.e.*, in one hour 15° of the earth's surface pass under the sun. Very well, then; if it is twelve o'clock in London, it will be eleven o'clock 15° to the west, and one o'clock 15° to the east; so you see if you were to go in a ship, and you took a clock with you which kept Greenwich time—and you know that it is twelve o'clock when the sun is exactly overhead—and you took an observation of the sun, and you found that it was twelve o'clock when your clock which kept Greenwich time gave the time as one o'clock, your time would show you to be an hour slow compared with Greenwich time; in other words, you would be 15° west of Greenwich. That, of course, gives you your longitude—the difference between Greenwich time and the time wherever you are gives you the longitude east or west, according to whether the difference is for or against Greenwich. You will thus see that had you got a clock which always kept good time, and could carry that with you, you could always tell your longitude by looking at the stars or sun, and comparing Greenwich time with your time. Unfortunately, clocks and chronometers, although constructed on most approved principles, and very wonderful machines, will not keep right for very long together; consequently, on a long voyage, the chronometer, however well it may behave when it is always in the same temperature, will invariably get out of order; you cannot, therefore, trust to your chronometer.

There is a clock that you can trust, however. When you look at an ordinary clock you see that it consists of a dial on which are marked certain figures, and that from the centre two hands move round it. But supposing, instead of having such a clock as that, you had one with the marks put on, not at regular distances, but anywhere, and instead of having two hands it had only one, which, instead of going regularly round the dial, simply wandered about in a peculiar manner, now over one dot, now over another, with the most irregular motion, you would say you had a very bad clock, and that the man who made that clock ought never to make another. Very true; but supposing it was the only clock you had, and you could not possibly get another, you would set to work to learn it—to learn what was the exact time for every possible position of that one hand over and amongst the various marks on the dial. Well, sailors have got a clock just like that. The dial-plate is the sky, and the marks upon the dial-plate are the stars. That one hand is the moon, and the sailor has the means of telling the exact Greenwich time by that clock, by simply noticing the exact position of the moon among the stars.

There is published in London a wonderful almanac, called the *Nautical Almanac*, which is published every year five years in advance, and in that almanac there is laid down the exact Greenwich mean time for every possible position of the moon among the stars. Consequently, all that the sailor has to do is to find out the exact position of the moon among the stars, and to turn to his *Nautical Almanac*, and having found that position against it he will see marked the exact Greenwich time. That is what is called the *lunar* theory of finding the longitude. I don't know of anybody else ever having attempted to make that most abstruse subject clear to a popular audience.

Having got your latitude and longitude, all you have to do is to measure one of these meridians of longitude and see how far it is round, and from that you can find the size of the earth, and can calculate its exact weight. If we can measure one of these meridians of longitude, we shall have our problem solved. I think I can make that clear. Suppose it is desired to measure what is called the arc of a meridian. If you had a box a mile long, and you knew that both sides were alike, if you measured one side only you would be quite satisfied; or if you knew that it was only possible to measure, say, half one side, you would measure that half side as carefully as you could, and then, multiplying by four, you would get the length of the two whole sides. It is not possible to measure right round the earth, but you can measure a certain number of degrees, and knowing that there are 360°, in the entire circumference, if you can measure, say, 10°, you have only got to multiply it by thirty-six, and you get the entire length round. This is how the arc of a meridian, as it is termed, is measured. First of all, a starting point is made, and a level plain—as level as it is possible to be found—is selected. Upon that is measured a straight line—an operation which is far more difficult than you, perhaps, would imagine: a straight line some miles in length is measured with the utmost accuracy. The measurements are made by means of bars about 6 feet in length, and tents are placed over them to prevent any alteration of their length by the heat of the sun or by cold winds. The measurements are examined by microscopes, and everything which scientific ingenuity can devise is taken advantage of to ensure the most absolute accuracy. Having measured this base, as it is called, the rest of the work is easy, and a number of stations are selected, some on one side, some on the other side of the meridian which it is intended to measure. These stations are some lofty objects, such as the top of a mountain or high hill, or tower, and the angles are observed which these stations make with the base of the line, and with each other. How this is managed is very simple. A theodolite, that is to say, an instrument used for measuring the angles, is put first at one end of the base, and then turned to the first station to be observed. Then the same instrument is taken to the other end of the base, and the same stations observed from the other end. Now, you see, by drawing this line we have made a triangular figure. Anybody who knows anything of trigonometry knows that if you know the length of one side and any two angles, you at once can find out the length of the other side. But supposing you had never heard of trigonometry, if you didn't know the difference between trigonometry and theology, you nevertheless can easily see that if I like I can draw that base line to scale upon a piece of paper, I can draw two lines to represent the other sides and get their exact length; that must be clear, I think, to the simplest understanding.

The next step is to observe in the same way the next station from the ends of this new base line, and so in this way successive stations are observed, and you get a perfect network of triangles all over the country. Now, from that same law of triangles, this piece of the arc of the meridian which we measure, being one side of a triangle, is known, and as we know the angles of the other sides, step by step, every bit of this arc of the meridian can be measured; and distances have been measured nearly 1000 miles in length, and there can be no possibility of a greater error in the total length than the length of this room in which we are assembled.

So we do know, with a marvellous degree of accuracy, the exact size of the earth, and the result of these measurements and every similar measurement has been to show that the earth is not quite round like a sphere, but that it is like a turnip—of course, the astronomer does not call it a turnip, he calls it an *oblate spheroid*, because it is flattened at the top and bottom, and bulged out in the middle. That is what the astronomer means when he calls the earth an oblate spheroid. If you went through the earth from top to bottom, the journey would be 26½ miles less than if you went through from side to side. Now, the exact circumference of the earth is rather less than 25,000 miles, and the distance through it, or its diameter, is, on the average, rather under 8000 miles. By this you can calculate the exact volume of the earth. You know that it weighs rather more than five and a half times as much as a globe of water the same size, and from that you can calculate by a method which, though it involves a number of figures, is one which can be easily worked by a boy in the Third Standard, that the earth's weight is about 5852 trillions of tons; and so, our problem being finished, I have only to thank you for the extreme patience with which you have listened to my attempt to make clear the method in which the earth is weighed and measured.

XI.

DEPTHS OF OCEAN.

AMONG the numerous grand and beautiful objects which we find in Nature, none exceed in grandeur or in beauty the mighty ocean, which in all ages has presented itself to mankind as the emblem of all that is vast, magnificent, and unfathomable. Even a superficial observer finds in the ocean much to interest him, much to enchain his attention, much to elevate his thoughts; but the earnest student of Nature desires to know something more than the mere surface. He knows that beneath the surface of the ocean there are many very interesting and important secrets hidden, which will absorb his attention still more than superficial facts, with which all are acquainted. It is to some of these facts that I now wish to direct your attention. Until a comparatively short time ago, our knowledge of the ocean floor, and what lies beneath the surface of the ocean, was very incomplete indeed; in fact, we may say until some twenty years or so ago our knowledge of the bed of the ocean and the character of the life, if any, to be found there, and the various other circumstances connected with the depth of the ocean, forming the basin in which it lies, amounted to absolutely *nil*. But within the period I have mentioned, very many expeditions have been fitted out by our own Government, the Government of the United States, and by others for experimental purposes to explore the ocean, and find out the character of its bottom, and whatever exists beneath its surface. I should like, on this occasion, to make what I have to say quite clear to you, and, therefore, I will ask you, first of all, to give me your attention for a short time, while I try to point out to you some of the more important tools which are necessary for exploring the bottom of the ocean.

One of the most important facts which we have learned about the ocean is its depth in various parts, and in order that the depth of the ocean may be sounded, it is necessary that we should possess some means of sounding or measuring that depth. The means usually adopted is a line with a weight at the bottom, which weight, of course, is allowed to run out from the ship, and as a general rule, when it gets to the bottom, a distinct check is felt upon the line, and then the depth is measured, the line being divided into what are known as fathoms—a fathom, you know, being 6ft. The number of fathoms is then ascertained in this way. The method I have mentioned is a very crude and simple one, and one which has been much improved upon of late years. There are various arrangements made so that when the line gets to the bottom of the ocean the weight drops off, and other arrangements also have been made by which small quantities of the soil at the bottom are brought up, so that they can be easily examined and their nature ascertained. One of these arrangements is called a clip, which is lowered to the bottom of the ocean where, as it were, it grips up some of the soil there. Then another plan is to have a tube which becomes filled with the material at the bottom, and is then brought to the surface. In all other cases it is necessary that arrangements should be made so that the weight may clip off when the line arrives at the bottom so that it may be the more readily hauled up again, and that the contents of the tube or clip, whatever it may be, may be brought up intact. Another important instrument which is employed for bringing up matter from the bottom of the sea is what is known as the dredge, consisting of an iron frame, upon which is fastened a bag, 4½ feet in length. The bottom part of the bag is of a much finer mesh than the upper half, the latter having a mesh an inch wide, while the lower half is very fine indeed, so that very little that gets into the bag at the top can get out at the bottom. This net or bag is strengthened by ropes, and then beneath it there is suspended some ironwork in the shape of bars, known as tangle-bars, because from these bars a number of tangles of rope are hung for the purpose of catching anything that might be at the bottom and bringing it up to the surface. In sounding with this dredge in deep water a heavy weight is usually hung upon it, generally about 28lb., and that, with the weight of the iron frame, causes it to sink to the bottom. After it is dropped, it is dragged a little along the bottom, and is then raised to the surface, bringing with it a quantity of the soil from the bottom of the sea, and also any marine animals which happen to be living there, together, sometimes, with other animals living higher up in the ocean.

Another important implement employed is what is technically known as the trawl. This trawl consists of a long bag somewhere about 30 feet in length, which bag has one side fastened to a bar of hard wood, the other side hanging down, being kept open by a number of pieces of rolled lead, which are put in so that it always has the mouth open. This is dragged along the bottom of the sea, and instead of closing up as it otherwise would, these pieces of lead keep it open, so as to bring up anything which may be below. It is fastened above by a kind of bridle to the chain which is let down from the ship's side; that, also, is loaded with weights, and the pieces of lead also assist in increasing the weight of the trawl in order that it may reach the bottom. The lower part of the trawl is generally lined with canvas, so that nothing but very fine soil can find its way through.

Another very important instrument employed in ocean-soundings is the thermometer. Of course, every one knows what a thermometer is, and the thermometers used for the purpose of ascertaining the temperature of the deep sea are in many respects similar to ordinary thermometers, except that they have a case over them, for this reason. When soundings were first taken in the deep sea it was found that the thermometers came up from the bottom with the tube squeezed out of shape by reason of the enormous pressure of water to which they were subjected near the bottom of the ocean. It was rightly guessed that this squeezing out of shape of the bulb of the thermometer must push the mercury up in the tube, therefore giving a much higher apparent temperature than was correct, and thermometers were therefore subjected to a test in a hydraulic press, which gave a pressure equal to that existing near the bottom of the ocean, and it was found that the mercury was forced up 15° when the pressure was three tons to the square inch, which is just about what is obtained some 3000 fathoms below the ocean's surface. To avoid this a glass case has been fitted over the thermometer, of just the same shape as the instrument itself, but larger, so that there exists a space between the water and the thermometer. Now, if this case were only filled with air, there would be a very great inconvenience arising from this arrangement. Air is a very bad conductor of heat—that is to say, it does not easily allow heat to pass through it; consequently, if only air exist in the space between the thermometer and the water itself, the instrument would have to be left at the bottom of the sea for some length of time before the mercury inside would be properly affected by the temperature and rise to the proper height; therefore the space within this outer case is partially filled with spirits of wine.

Having mentioned the principal implements which are employed by the explorers of the ocean's floor, I should just like to bring before you as plainly as possible, and in as few words as I can, the principal results of those explorations. First of all, with regard to the depth of the ocean. The general way of stating this I find in books, is that the depths of the ocean are much about the same as the heights of mountains on the land—*i.e.*, that you would find the deepest parts of the ocean more than five miles deep, five miles, as you know, being about the elevation of the loftiest mountain in the world. This idea is not quite correct. The ocean which lies between this country and America, the Atlantic Ocean, has been much more carefully explored than any other part, and we find that the average depth of it is about 3000 fathoms, which is not much more than two and a half miles, while the greatest depths, quite exceptional, are under four and a half miles, so that the general statement I have alluded to is not quite correct. In the Pacific the larger ocean, we find the depth does not probably exceed from two to three miles.

Important information has been gained by means of these various soundings as to the nature of the ocean floor, especially that of the Atlantic which lies between England and America. If you look at the map of the world, you will find that in the eastern hemisphere you have Europe, Asia, and Africa, and on the other side, America. You will find that there is a considerable resemblance between the two sides of the land; you will find, in fact, that where the land is hollowed out on the western side, there is a corresponding bulging out on the eastern side, so that if it were possible to bring the land in one hemisphere back to the land in the other, you would find that one part would fit in the other, very much like the pieces of a child's puzzle. Starting from Europe, it is found that just near the land a narrow terrace extends out into the sea, and there the sea is very shallow. Then, just beyond this terrace, which fringes the land as it were, there is a sudden fall in the depth. There is evidently a deep valley, forming one of the basins of the Atlantic. Then, running down the middle from north to south, there is throughout the whole

Atlantic Ocean a ridge, and on the other side of that—*i.e.*, on the western side of that ridge—there is another deep valley. That is divided into two portions, so that we have a north-west basin and a south-west basin, which is much narrower than the northern. In starting from Ireland, let us say, to go to America, supposing it were possible to walk along the ocean floor, you would first of all go along the lofty terrace I mentioned, then suddenly down into the valley, where the depth would be something like 18,000 feet; then you would cross the ridge, where the depth of the ocean would of course be much less, and then you would pass into another very deep valley which would fill up about half the bed of the Atlantic, and then you would rise first of all gradually, and then more suddenly, until you came to America. So much, then, for the shape of the Atlantic, and the form of the basin which holds the mighty ocean between the continents of Europe on the one hand, and North and South America on the other, and as I have already said, the depth is about 3000 fathoms.

Another important fact connected with the ocean is its temperature, and this is very interesting, as you will presently see. We find as a general rule that, first of all, when you let the thermometer down there is a very rapid fall in the temperature, then it decreases more gradually, and if the water be shallow it continues to decrease to the bottom; but if the water be deep the temperature gets lower till you come to a certain depth, and then from that depth to the bottom the temperature remains the same. You know, of course, that at the Equator (the imaginary line which runs round the earth at its centre) the temperature at the surface is very high, but it is found that when you try the temperature of the ocean underneath the surface water, it is found that the water is very much colder until near the ocean floor, where you have a temperature which is only just above the freezing point of fresh water, 32°. This is a rather strange thing. In the very hottest part of the world you find at the bottom of the ocean the coldest water, except you go right up to the north or done to the south. If we go northwards from the Equator and the temperature at the bottom is tried again, it gradually increases, although it never reaches anything like the temperature of the surface except in the Arctic regions, and so we have these peculiar phenomena—underneath the surface water we have at the Equator a mass of cold water which gets warmer as you go northwards, though I may tell you as you go south it keeps somewhat about the same temperature. This means that the water is in motion, because you know very well that if you had a mass of warm above a mass of cold water, and they stopped still for any length of time, both masses of water would acquire the same temperature; consequently the fact that the water below at the Equator is so much colder than that at the top shows that the water at the bottom must be moving, as well as the water which we can see to be moving, and it also shows us that the water must come from a place where it must be colder, or else it would not keep cold, and it is surely probable, therefore, that there is constantly coming up into the Atlantic, welling up as it were, a quantity of cold water from the ocean round the South Pole.

This was for a long time an interesting problem that no one could solve. How was it that this water constantly welling up in the Atlantic and going northward was kept at about the same temperature all over the ocean? The answer to that question is simply this: To the north of the Atlantic there is a very large quantity of water evaporated —that is, taken up by the heat of the sun; that travels through the air in the form of clouds back to the south, and there these clouds come down again to the ocean in the form of very copious rains. You are probably aware that there is a great circulation of water constantly going on all over the world, partly on the earth and partly in the clouds. Every day the sun is taking up from the surface of all our oceans, seas, rivers, and lakes a quantity of water, and when rain falls it takes it up also from the moist ground. This moisture is taken up into the air in the form of an invisible vapour, and in the upper regions forms clouds, and ultimately comes down again as rain. In this way we have a direct circulation of water through the earth and clouds, and it is this circulation which assists the circulation of the water itself in the ocean.

We have what are called currents set in beneath from the south, and we have surface currents flowing backwards towards the south, and that partly makes up for the water which comes from the ocean near the South Pole, but not entirely; the other water travels through the air back again to the spot from whence it came. There is another current which I must say something about, though some may have heard about it before. Most people have heard of what is known as the Gulf Stream. I should like to say something about it. Our climate, you know, is very much warmer than the climate of America in the same latitude —that is to say, at the same distance from the Equator —and there has been a great deal of discussion as to the exact cause of it. Among other causes this Gulf Stream is supposed to hold a prominent place. Now, the winds which prevail near the Equator are always blowing from the east, and consequently this will tend to drive the warm water near the Equator towards the west, forming what is known as the equatorial current; and this current, when it gets to the south of America, splits into two parts, one part going down the coast of South America, the other going round into what is known as the Gulf of Mexico. A great part of it goes back again into this equatorial current, forming a kind of eddy, and in this eddy you find a quantity of seaweed. This mass of seaweed covers the ocean for many miles, and is known as the Sargasso Sea. But although the greater part of the Gulf Stream goes back again to where it comes from—viz., into the warm water of the Equator—the rest sets out on a journey north-eastwards. It is about thirty miles wide, 2500 feet deep, and this immense current of water has a very high temperature, something like 85°—that is to say, a temperature which is above that marked "summer heat" upon the thermometer. That volume of water, you understand, is setting out from the Gulf of Mexico in a N.E. direction towards the shores of Western Europe, and as it gets out it soon gets cold, and spreads out into the water surrounding it, and then you get a drift of it setting towards the west of Europe, including, of course, Great Britain.

Now, according to some, this stream of warm water is the main cause of the greater warmth of our climate in winter than that of America in the same latitude; according to others it has very little to do with it. The truth probably lies, as it so often does, in the happy medium between the two extremes. On the one hand there can be no doubt that the effects of the Gulf Stream have been exaggerated; but, on the other hand, it is also, I think, quite certain that by some they have been underrated. This Gulf Stream has not everything to do with the mildness of our climate, still I think it must be taken as an important factor in the very marked and beneficial difference which exists between our climate and that of America in the same latitude. These currents, I know, although currents of water, are somewhat dry, they are somewhat difficult to understand; but I venture to bring them before you for this reason: I want you to see that the great mass of water which covers the greater part of the surface of the earth has in it currents of waters constantly moving in different directions, and these movements have a very great deal to do with the climate, and also, no doubt, with life of every kind.

Another important thing which we have to notice in regard to recent discoveries is as to the character of the ocean's floor. What is it like when you get to the bottom? That is the inquiry which will very naturally be made by any intelligent person who desires to know something about what is underneath the surface of the sea. I will try and tell you. From the results of recent explorations, it seems perfectly clear that a great part of the bottom of the Atlantic is covered with a deposit which is very much like the chalk which we find forming such an important feature in our own country, and which also extends some way into Europe. Now, it is found that at a depth of from 400 to 2000 fathoms the bottom of the Atlantic is covered with a kind of whitish paste, and this, when examined under the microscope, is found to consist mainly of the skeletons of extremely minute animals; its chemical composition being what is known as carbonate of lime. As I have before had occasion to tell you, a large number of minute animals which live beneath the surface of the ocean have the power of extracting from the water carbonate of lime, or chalk as we call it, and this substance forms their skeletons, which, at the death of the animal, falling to the bottom of the ocean, form there a deposit which in its nature and origin very closely resembles the chalk with which we are all familiar.

Now, I have said that we are all familiar with chalk. In a certain sense, perhaps, we are, but perhaps we do not all know what chalk is made of. I will try and tell you. If you examine chalk, or this deposit now being formed beneath the Atlantic, you will find that it is made up to a large extent of minute shells, most of them so minute that to the naked eye they appear to be only little tiny specks, but when examined under the microscope they are seen to be regular forms, many of them of very great beauty. These little shells are chambered shells, and their peculiarity is that that they have a number of minute holes in them, and they, or rather the animals which they contained, have consequently been called " hole-bearing animals," though the scientists use another word—*foraminifera*, which, however, means the same thing. In the "Challenger" Expedition, sent out a few years ago, they were upon one occasion so fortunate as to obtain one of these little animals alive, and they then found that if this animal is in sea water, and left alone quite happy in his mind, a number of minute processes are sent out from all those little openings in the shell, which little processes are of a kind of white jelly-like material. These minute threads are obviously put out in this way in search of prey, so that when anything eatable comes in the way of them it gets entangled among them, and is then drawn in by the animal and made use of for food. If the water is disturbed, or the animal is in any way irritated, it immediately withdraws these threads and altogether disappears inside its shell or skeleton. Of these animals there are many varieties, differing from each other in detail, but similar of course in general character; but the one form which predominates throughout the whole chalk formation, be it ancient or modern, is that with the big name, *foraminifera*, which has given its name to the ooze which comes up from the Atlantic where the depth does not exceed 2000 fathoms. Mixed with these small shells there are some minute bodies which are probably parts of the remains of certain organisms, both animal and vegetable, not living at the bottom of the sea but near the surface, their skeletons falling when the organisms died.

This is one kind of deposit found at the bottom of the ocean, but there is another kind which is very important, inasmuch as it covers, on the whole, a larger space on the ocean floor than does that which I have just been speaking of. This other substance is a kind of red clay, and that red clay is formed at the greatest depth. If you go down to a depth of 2000 fathoms you get, as I say, this chalk ooze, but at depths greater than these it is found that the chalk ooze disappears and red clay takes its place. You must not suppose that there is a sudden end to the chalk ooze, and as sudden a commencement of the red clay : there is, on the contrary, a gradual transition from the one to the other. When you get a little below 2000 fathoms you find that the ooze, instead of being white, becomes grey, and then gradually passes from a grey to a reddish-brown and pure red, which is found only at the lowest depth—that is, below 3000 fathoms. This red clay is very interesting, because its origin was for a long time a matter of doubt ; but I think you will find that we now have something very wonderful to relate about it.

It has two or three origins or sources. First of all, in the chalk ooze there are found a number of pieces of pumice stone and other pieces of rocks which we know come from volcanoes. Some of these pieces are as small as a pea, some as large as a cricket-ball, and these pieces have evidently been brought from the land wherever there were volcanoes, in the shape of clouds of ashes which you know frequently float very many miles, then gradually falling upon the surface of the water, they sink to the bottom. In the chalk ooze, then, a number of pieces of volcanic rock are found ; in the red clay they are very much more numerous, and to a certain extent the red clay thus owes its origin to mineral or inorganic sources. In addition to that there is another source, and that is in some very peculiar animals which are found near the surface of the ocean. These animals, the *radiolaria*, unlike the *foraminifera*, have not always a complete skeleton. Sometimes they have none at all; sometimes the skeleton is only represented by a few small spicules, which look like pieces of carbonate of lime ; sometimes by a number of plates, and sometimes the skeleton is quite complete. These also have a number of threads proceeding from them, and these little animals are altogether very interesting. The flesh of these animals is of a peculiar reddish-orange tint, and, as they are always dying, their soft parts decay, and they fall upon the deep parts of the ocean floor, and to a large extent compose the red clay of which I have been speaking.

I dare say those of you who have been thinking about the matter at all will say, Well, why should the chalk appear upon one part of the ocean floor and the red clay upon another part? If the animals lived on one part of the ocean floor we could understand that in one part animals produced a white clay and in another part other animals produced red clay, but, knowing that the ocean is always in movement, we should, wherever the red clay animals come from, expect them to be scattered more or less over the whole floor of the ocean. The answer to that very important question is this: By means of some chemical decomposition in those parts of the ocean where the red clay is found, the white clay has been removed—broken up and dissolved—and only a very little of it left, that little going to form a very small part of the red clay. So you see that, taking the whole of the Atlantic floor, we find that going down to a depth of 2000 fathoms we have white clay at the bottom, and wherever it is deeper than that we have either grey ooze or red clay, the red clay being found purest in the deepest parts.

These facts are, I think, of considerable interest, and show you, if nothing else did, what a vast amount of life there must be beneath the surface of the ocean, to form these immense deposits; and when you remember the enormous area which the chalk covers upon dry land, and the enormous thickness of the deposits, you will see that many ages must have been required to form those tall white cliffs for which Albion is so justly famed.

There is another important point connected with the explorations of the depths of the ocean, which I should like to speak to you about, because I think it intensely interesting—viz., as to the character of the life which is found to exist beneath the deep sea. At one time it was thought that there could be no life existing beneath the ocean at any great depth, and that any life that was found in the ocean must necessarily be near the surface. This, of course, at first sight, seems probably a correct notion ; because you must remember that at the bottom of the ocean it is totally dark, and the pressure must be something enormous, and from what we know of the character of the water, its density and its composition do to a certain extent differ from that nearer the surface; but it is now a clearly established fact that life exists at all depths beneath the surface of the ocean; for just as in travelling from a plain to the top of a mountain you find life existing, although in small quantity, even on the topmost peaks, so, as you go downwards in the ocean, you find it in the very lowest depths. As a general rule, however, it is found that only the higher kinds of life are found near the surface; the animals found near the bottom belong to the lower forms of life, and are also usually, though there are many exceptions, of a smaller type than the same kind of animals existing near the surface.

Then, again, it is found that there seem to be in the ocean two belts of life, one near the surface, and another belt near the bottom, and between the two there is an area where life, though by no means absent, is not present in any very great abundance.

Such are the chief facts about life beneath the surface of the ocean. I dare say, however, you would like to know something more of the animals which are found there; I will, therefore, just point out to you one or two of the principal forms, and give you some idea as to what they are like. I have already mentioned two forms—the *foraminifera,* or hole-bearing animals, which form the chalk ooze, and also other minute animals which form the red clay, the *radiolaria;* but besides these we have upon the ocean floor or near the bottom other very interesting animals; and, first of all, I will notice the sponges. I dare say some of you look upon a sponge as a single animal; it is, in fact, a colony of animals. The ordinary sponge which we use for toilet purposes is really the skeleton of a large colony of minute animals. In some places we find a sponge, not in the same form as we are usually acquainted with it, but in the shape of a vase, rather narrow. It is found attached to the bottom of the ocean, and is composed of two layers, an inner and an outer, and at the top there is a wide opening which we may call the gateway of the colony. It is found that all over the surface of the sponge you have a number of minute openings, comparable to the pores of the skin—in fact, they are called pores—and through these openings there is a constant rush of sea water which thus gets inside the sponge and goes outside through the gateway, or mouth, so that there are, as the Irishman would say, a large number of entrances in, but only one entrance out. In this way, you see, there is in a sponge colony a constant current of water, bearing, of course, articles of food, going through these openings, and carrying away, as it passes out at the mouth, any refuse matter.

In the centre layer we have a number of little bodies, which are little cells, each one containing what is called a *nucleus*, having a single fine hairlike process, which is directed into the centre cavity. These little cells are little animals, they are, in fact, the inhabitants of the sponge colony, and we may compare their existence to that of the people who live in Venice, where, if you want to go out, you step into a boat, or gondola, and where, of course, all provisions are brought to your door, and all refuse taken away in the same manner. Each one of these little sponge animals is very much like a dweller in Venice. A constant stream of sea water is passing by, and that water contains minute organisms which the sponge animals can live upon, and into that water goes all the refuse that has to be got rid of, and so their life is carried on.

The skeleton of the sponge has generally a number of minute needles like pieces of glass; some of them are very beautiful in their shapes. These are the so-called spicules. The sponge as we see it is, of course, only the horny skeleton of a whole colony. The little spicules I mentioned you can shake out of a new sponge in great numbers, in the shape of a white powder, but this, examined under the microscope, presents a variety of beautiful forms.

You will remember that these sponges are found at the bottom of the sea. There are, of course, various kinds of sponges, and one kind is peculiarly interesting, inasmuch as it is just like a peculiar fossil which is found in the chalk, showing us, if we needed any further proof, that the chalk was no doubt formed in much the same way as the white ooze of the Atlantic.

Then at the bottom of the ocean we find animals, such as the star-fishes and all their relations. Star-fishes form a very large family, and have a very great many relations, and some of these relations of course differ very considerably among themselves, not as relations sometimes do, but as regards their structure. Still the general features are the same, and therefore if I describe the common star-fish to you, such as you pick up any day on the sea-shore, you will have some idea as to what this interesting family is like. You know then that the star-fish consists of a central plate or disc, from which radiate, usually, five arms, or, as they are sometimes called, fingers. In some star-fishes the number exceeds five, but that is not often the case; as a general rule the number is limited to five. You have these five fingers then; on one side of the star-fish you will find that there is a mouth, and that mouth, I may tell you, leads into the stomach, as most mouths do, and this stomach is prolonged into the arms, so that the stomach, you see, is tolerably capacious. Then round the mouth you find a circular vessel, which has also connections with five branches, going to each one of the arms. This vessel and its branches contain sea water. Along the arms of the star-fish you have probably noticed little suckers which are in connection with the branches of this circular water-tube. These little suckers, of which there are usually five rows in each arm, are used for purposes of locomotion by the animal. This star-fish is rather high up in the scale of nature. He has a very distinct nervous system, which consists of a ring round the mouth and branches going into all the arms. It has also a system of blood vessels which is somewhat similar. Some of these star-fishes which come from the bottom of the sea are very beautiful indeed. There are also brought up what are sometimes known as stone lilies. When you find them in a fossil state in the rocks they have a stalk which may be longer or shorter, and a very beautiful flower-like top, whence their name of stone lilies when found in a fossil state. Their proper name is *encrinites.* With regard to these hard names, a few of which I am obliged to use, it must be said that it is necessary that they should be used. Every one knows what a lion or a bear is; therefore we can call those animals by a name that is generally known; but when fresh portions of the earth are exposed, and animals and plants are discovered which were hitherto unknown, names have to be given them, and such names are given them as will be understood by scientific men all over the world. In this way, therefore, as in the case of these *encrinites*, words are used which are derived from the Greek or Latin, and in this way scientific men of all nations can understand the meaning of any term which is applied to a particular individual or species. This rule has been applied to the *encrinites*, and I may tell you that there are very many interesting specimens of the stone lilies to be seen in the Geological Museum, to which place I hope I shall soon have the pleasure of accompanying a few of my hearers.

These are the principal animals which we meet with. Others that we find near the surface are of course better known, and a number of fishes of very curious and even comical appearance. In addition to these we also find beneath the surface of the ocean a large number of animals who are more or less closely related to our lobsters, crabs, and shrimps. About the first-mentioned I shall have something to tell you next week. With regard to the vegetable life, I must say a word or two about that. The vegetable life in the deep sea consists mainly of various kinds of seaweed, and in addition there are some very minute organisms only to be properly seen under a very powerful microscope. They bear the hard name of *diatoms*, and occupy a sort of borderland between the animal and vegetable kingdom. They are very generally taken to be vegetable. As a general rule it is found that no seaweed exists in any quantity upon the actual surface of the ocean, though they are only a very little depth beneath it. All the vegetable life which is found in the ocean is comprised in the first 600 fathoms. When you get below the depth of about 600 fathoms all vegetable life ceases, and whatever species of it is found below that depth is dead. Very few vegetable forms are found floating on the surface. However, if we call the *diatoms* vegetable, they form an important exception, because they are found almost invariably on the surface. Then, again, you will remember, that just now, in speaking of the Gulf Stream, and the eddy caused by a large part of that stream turning southwards and going back again to the Equator, I mentioned that there was a large floating mass of seaweed many hundreds of miles in extent, and called the Sargasso Sea. That, of course, forms another exception to the rule just stated, that vegetable life is not often found floating upon the surface.

The time, however, which we can devote to that subject at present is quite gone, and while thanking you for the attention which has been given to me, I will hope that I have said sufficient to show you that while the ocean has much of beauty and much of grandeur to those who simply observe it superficially, it has locked up within its lowest depths secrets more wondrous and beautiful still, which are to be made known to whosoever cares to seek for them.

XII.

LOBSTERS AND THEIR RELATIONS.

IT is related that the French Academy, when compiling their celebrated dictionary, having defined the word "crab" as the name of "a small red fish that walked backwards," and being anxious that the definition should be quite correct, sent it to the celebrated naturalist Cuvier for his approval. Cuvier returned it, and said in a note that it was a most admirable definition, only the crab was not red, it was not a fish, and it did not walk backwards, otherwise the definition was all that could be desired. We are met together on this occasion to talk about an animal, say closely related to the crab; in fact, its first cousin—the lobster—and I hope, during the short time I shall occupy your attention, you will learn something much more correct about the nature of the lobster than the French *savants* knew about the crab. As I said before, the lobster is a very near relation indeed to the crab, and, therefore, the French definition of the crab, had it been correct, would also have applied to the lobster; but, as we all know, it does not, and, therefore, one of the first things we have to inquire is, what is a lobster?

This question brings us to a very important and interesting subject in connection with science especially, and with knowledge generally. You know that if we want to get any real, useful knowledge of a whole heap of facts, it is necessary that we must do something to reduce them to order;

we must classify them. If any of us should come into the sudden possession of a library consisting of a whole multitude of books all piled together without any regard to order, in order that we might improve ourselves by their use and systematic study, the first step it would be necessary to take would be to arrange them in some kind of order. Even if we were not going to read the books, that our object was not such a lofty one, and we only wanted to put them on the shelves in somewhat decent order, the first thing would be to classify them. We might use any method we liked; we might put all the red-covered books together, all the blue-covered books together, and so on; or we might put all the books of history together, all the books upon science together, and so on with the rest. In that way we should, of course, arrive at a very reasonable way of classifying the books, and so arrange them for our use.

Again, suppose a person had left me a quantity of tools; the first thing I should do would be to put them in order. For instance, I should put all the tools for punching together, all the tools used for drilling together, and all those used for shearing together, and so on. I should do this in order that I could get the best practical use out of my tools, and know where to put my hand upon the one I required at any time. Just in the same way the naturalist, when he proceeds to the study of Nature, finds that the first thing he must do is to classify the various animals or plants with which he comes into contact. I thought I would just say a few words about this classification, because I know the terms which are employed in the system generally in use belong to the class usually termed "jaw-breakers," and very often prove discouraging to those who want to know something about the numerous living beings which this earth produces.

It takes very little observation upon the part of even a very ordinary observer to see that you can make two great divisions of animals, which division is, into such animals as have a backbone and those who have none. We know that an ordinary fish has a backbone, and we also know that the lobster has not; therefore we very soon arrive at the conclusion that Cuvier was quite right when he said that the lobster was not a fish. I know that it is convenient to call lobsters, oysters, and mussels, and animals of that kind, shellfish; but now we are speaking scientifically, and therefore must be quite exact.

If, then, the lobster is not a fish, what is it? Well, it belongs to a class of animals which includes such species as these, all the insects, mites, scorpions, all the spiders and centipedes, and all the lobsters and crabs, &c. All these animals, we find, although differing from each other in several minor details, are alike in this respect—their bodies are made up of numerous jointed segments, and they all have jointed limbs; therefore we say that the lobster belongs to the class of animals with jointed limbs, and I should like to point out to you a few features of its structure, and I hope that some of you, at least, may obtain therefrom a great deal of useful information.

When we look at the lobster we see that he is coated with a very strong protective covering, which is really its skeleton. When you take a lobster and do what most sensible people do, except late at night, make a meal of him, you don't find any bones inside, as you would in an animal that had a backbone; all the soft parts are inside, and all the hard parts are outside, forming this hard covering or skeleton. This skeleton consists of a part which is commonly called the head, really answering to the head and thorax, or chest, and a part commonly called the tail, but is not, because it is really what is known as the abdomen, which is terminated in a kind of fringe which is really the tail—only a very small portion of that which is ordinarily called the tail.

On examining the lower part of the body of the lobster, we find that it is made up of six parts or segments, each of which is somewhat in the form of an arch, and is joined underneath by a sort of band, somewhat circular, to the spine in the middle. Each one of these segments is very beautifully jointed together, so as to be perfectly movable on the others, and in order that the movements may be as easy as possible, and without any friction whatever, the front part of each segment is very beautifully smoothed off, so that there is a kind of facet upon which the segment in front easily moves. When we come to the front part of the lobster, we do not find this separation into pieces, but if you take a lobster when it is very young, in fact, before it is hatched, you will find that there is a distinct division into segments of the front as well as of the hinder portion; and not only that, we find in all these animals with jointed limbs that each segment has a pair of limbs. You see that in the case of the lobster these limbs in the abdomen consist of what are called swimmerets, because they are used by the lobster for swimming.

As we go nearer the head, you find there are also a number of limbs there, which indicate that there was at one time or other in the history of these animals a division into segments of the whole body, and not merely the hinder portion. Let us look at these limbs a little closer, and see what they are like. We find that the six hinder segments have six pairs of what are called swimmerets. Going still further forward, four legs; they are legs because they are used for walking. When the lobster is taking his constitutional on the sea-shore in shallow water, he uses these limbs for the purpose, but when he swims he uses the swimmerets upon the segments which form the lower part of his body. There are four pairs of these walking limbs.

We come now to those formidable-looking claws. These claws are very important organs. They are made up altogether of several joints, and you will find that these joints are put on in various planes, as we say; my forearm and upper-arm are in the same plane, moving in the same direction. These joints move in different ways, so that the animal can make circular movements, and if you should not happen to be on very good terms with the lobster, I should advise you to keep at a respectful distance when he is alive and exercising with these claws. We find that the lobster uses one of these claws for the purpose of anchoring himself. After he has been swimming about for some time and he wants to stop and think, he lays hold of something with this claw, which is the one with the little rounded teeth. While he is resting there, there probably goes along something very tempting in the way of food, and then he uses the other claw, which has the small saw-like teeth, to lay hold of it. Then, of course, he carries it to his mouth, also assisted by the other claw. Again, while he is dealing in the manner I have described, he may see some one against whom he has a grudge, or, perhaps, one of those bipeds calling themselves men may come and interfere with him, and then he flourishes his claws, and very probably he, as the lawyers say, inserts a "claws," or rather a pair, and if he does so there is no necessity for obtaining information as to the effect, you will know it yourself; because those claws are very powerful nipping organs, and you would probably make a remark if one of them caught hold of you.

Continuing our examination still further towards the head of the lobster, we find three more pairs of organs which are very curious. They are partly used as jaws, and partly as feet. Now the only connection that our limbs have with our teeth or jaws is when we hold our jaw in the agony of toothache. The lobster, however, has three pair of foot-jaws, which are thus named, because, as I have said, they are employed partly for walking purposes, and partly as grinders. Next to these we come to two pairs of true jaws, and then next to those we come to a pair of tooth-like processes called mandibles; and then right in front we find two pairs of feelers, a large pair which are longer than the whole length of the animal, and a very much shorter pair. Then, just underneath this pair, we have a pair of eyes fixed on movable stalks. Thus in the lobster we have twenty pairs of limbs, and we are therefore justified in saying from this, that the body of the lobster is really made up of twenty segments, and that in the front part fourteen of these segments are paired together to form what is called the cephalo thorax—the head and chest portion.

I must say something more about this skeleton before we leave it, because it is very interesting. The front part consists of a great shield-like piece, which is called the *carapace*, or shield, which carapace covers over the head and chest. I need not, of course, tell you that the lobster in its natural state is, in colour, a kind of black, sometimes brownish black, or greenish black, according to the age of the animal, and that there is something in it which turns red on boiling. I was told, when a youngster, that the turning red was caused by their being stirred up with a red-hot poker, but I have never been able to verify the truth of that statement. Now, if you or I want a new suit of clothes, we have not very much trouble in getting them, if we have got the money, nor in pulling off the old clothes and putting on the new ones. But with the lobster it is a very different matter altogether.

Now, our skeleton, being inside of us, grows as we grow, and you know we grow gradually; but the lobster and his relations grow by fits and starts, and for this reason every suit of clothes they have, or, in other words, every skeleton they have, is of such a hard, rigid character, that there is no room for them to grow, and when they want to grow they must cast the old skeleton off and get a new one. Ordinarily speaking a lobster is a very pugnacious animal, and one gentleman who had a cray-fish, which is nearly the same thing as a lobster, gives a very interesting account of what happened when the animal had to change his coat. He says that at all ordinary times the cray-fish, which was kept in a small aquarium, was very pugnacious. Whenever the gentlemen went near it the cray-fish would endeavour to lay hold of his fingers. One day he came in, and, to his surprise, he found that the animal was quite frightened; directly he came into the room it seemed to be in a terrible state of fright, and then he found when he went to the aquarium what appeared to be another cray-fish lying by the side of him, and to his surprise he found that it was not another cray-fish, but the old shell or skeleton of the cray-fish which he had cast off, and there was the poor animal shivering, with nothing to cover his body. He remained like that for some few days, and then gradually the new shell got as hard as the old one, and then it was observed that he was bigger than he was before, and also very speedily recovered his courage, beginning to show fight with even more daring than usual.

The curious conduct of the cray-fish is explained in this way. When the cray-fish, or lobster, is going to shed its coat, which he does three or four times, he retires into some quiet place out of the way of any enemies who might take advantage of his desperate situation, to pay him off any old score. I may say that lobsters do occasionally take a mean advantage of their brethren in this respect. It is then found that the animal lies on his back, and the lower part of his body begins to be violently agitated, and then the whole body seems to be thrown into convulsions. Then it seems that the animal, having had one fit of convulsions, has a rest. Then there is another movement of the lower part of the body, and he then pulls himself right out of the carapace, which covers the head and thorax, until it just hangs by the front part, and then another violent convulsion takes place, and it is thrown off altogether. Then he takes a dart forward, and leaves the hinder covering behind him. In this way the animal gets rid of its shell, and the curious feature of the process is that, as soon as the shell is cast off, all the old rents in it close up; and if you see one of these shells lying on the sea-shore, it looks exactly like a lobster, and you only find the difference when you take it up and discover it to be only an empty case. The animal, after casting its shell, has only a very delicate covering, and it evidently appears to be very ill; indeed, those violent convulsions by which the animal gets rid of its shell sometimes terminate in its death. It remains in retirement until its new shell gets quite hard, and then it comes out again to face the world. During the interval between the casting of the old shell and the hardening of the new one, the covering of the lobster is very elastic, allowing the lobster to grow, as he does, with great rapidity; and so we see that what I said about its growth is quite correct. It does not grow regularly day by day, but by fits and starts.

A peculiar feature to be noticed in this casting of the shell is that sometimes, in its endeavour to get free from the old covering, the lobster will leave one of its limbs behind him. No one, of course, when getting out of an old coat, leaves an arm behind, although we may, perhaps, tear a sleeve out of the coat; but in the case of the lobster it very frequently happens that one, or even more limbs, or sometimes part of a limb, is left behind. Again, it frequently happens, in a stand-up fight between two lobsters, that one at least of the combatants loses one or two of his limbs; and, again, if any one should catch hold of its limbs or claws, so that the lobster cannot get away, he simply leaves the said limb or claw behind him, just as a pickpocket might leave his coat-tails in the hands of the disappointed policeman. It is found that a limb always breaks off at the first joint, because there the attachment is slighter. This, of course, is a very strange proceeding on the part of the lobster, but

Nature seems to take pity upon him, and the next time the lobster casts his shell a new limb begins to grow. First of all, you will notice that the part where the limb has been torn off gets covered over with a kind of horny casing. It begins to grow much as a bud grows into a branch, and then it takes on the character of the limb which it is replacing, but for a long time it remains very much smaller than the limb which it replaces, and it is not until the shell has been cast for three or four times that the limb obtains its full proportions. This accounts for the fact that we sometimes find lobsters with one limb unlike the fellow one on the other side—that is, as the Irishman said, you have a pair of odd ones. This most frequently happens with those big claws.

Now, as to the animal's general interior. You know, of course, that inside the skeleton or shell of the lobster, we have a quantity of what is ordinarily called flesh, comparable to the flesh we find outside the skeletons of the higher animals. That which we ordinarily call flesh the philosopher calls muscle, and it is, as you know, the especial property of muscle to contract—that is to say, to get shorter in length. This fact was made familiar to us in our boyhood by a process known as "feeling your muscle," in which you put your hand upon a companion's upper arm : he bent his arm, and as he bent it you could feel the muscle get thicker, and appear to swell up ; and we know that it got thicker and shorter as it pulled up the lower arm. That is the special property of muscle wherever you find it, and this immense quantity of flesh—immense as regards the size of the animal—which is inside the lobster's shell, has just the same functions. That juicy flesh, for instance, in the lower part of the shell has for its function the moving backwards and forwards of that part of the body and the flapper-like tail, and thereby assist the animal in his locomotion. In the same way all the fleshy substances which you will find inside the claws and limbs, have for their purpose the moving of those limbs upon their various joints.

We see, then, that we have one important essential to life in the lobster—muscle; but then, in order that the muscles may contract and produce those movements, it is necessary that they should be stimulated. It is necessary that it should be set to work, and we know in the case of ourselves, when we bend our arm, for instance, a message comes from a certain mass of matter in our head, which we call our brain; that message passing along certain cords, which in their formation are similar to telegraph wires, and are called nerves, causes the muscles to contract and the limb to move. The question now arises, has the lobster anything like that in his system? Yes, he has. He has not a brain, he has not any great taste, probably, for scientific lectures, still less for one upon his stiffened corpse; but he is, nevertheless, capable of performing actions which indicate that he has a certain sense, though only, of course, a lower sense, of a will of his own. For instance, if he comes across an obstacle in his path he can readily turn on one side, and if he sees anything in his native element, the look of which he does not like or is afraid of, he gets out of the way. If he sees a friend whom he would like to pommel, he makes after him sharply and pays him out; and if he sees a delicious morsel he performs a series of more or less complicated movements to get hold of it, and to make a meal thereof. All this shows us that somewhere or other the animal must have something which, roughly speaking, answers to our nervous system, as we call it—the brain and the various nerves in our bodies.

In the lobster we find there are altogether thirteen lumps of nervous matter, which, when we examine them, we find to be similar to the nervous matter found in our own brains and bodies. There is one large lump just above the animal's gullet, another one below—these two lumps being joined together by white cords, which answer the same purpose as similar cords do in the higher animals. In the thorax there are five other such lumps, connected together by double bands. Then there are in the abdominal portion six other smaller lumps of nervous matter, connected together by a single cord. All these lumps give off a number of fine nerves to the various organs in their vicinity, and it is through actions which take place in these lumps of nervous matter that the various movements of the animal take place. For instance, the animal is on the look-out for a dinner. He sees something nice, and immediately sets to work to get hold of it. What happens is this. Rays of light from this said dainty morsel affect the nerves of sight, which convey them to this first lump of nervous matter, from whence, through the connecting cords, certain messages are sent off, which are something to this effect, we may suppose: —There is something good to eat; look sharp and get it. Then from the various knots of nervous matter in the chest go out messages to all the muscles to contract, and set the limbs in motion, and to lay hold of the desired object. So, you see, a series of complicated movements are brought about in this animal, as they are brought about in the higher animals for the purpose of supplying the needs of the animal's body.

The question arises now, Can the animal see, hear, or possess the sense of touch, as we can? First of all, we find he has a pair of eyes, and we know that in the bones of this pair of feelers he has a small ear, which has all the essentials of an organ of hearing, and we have every reason to believe that these feelers themselves are, as their name implies, concerned in the sense of touch. You say, What is the good of working any farther? If he has got eyes he must be able to see. That is true, but only to a certain extent. The question is, Does he actually have a distinct vision of objects? Has he any consciousness? If I am walking across a road, and see a cab coming along close to me, I jump out of the way. My brain has nothing to do with that action; what knowledge I have of it takes place after the action has been performed; consciousness has nothing to do with such an action; if I were a lunatic I should probably do the same. We are daily performing a number of actions of great complexity. All that we know with regard to the lobster is that he performs actions of this kind which do not necessarily involve consciousness; and so, although the animal has eyes and ears, we cannot say whether it actually possesses consciousness or not. It is probable that it is nothing more than an animated machine, and just as you may, by touching certain notes on the pianoforte, produce certain harmonious sounds, so the various circumstances by which this animal is surrounded may so act upon its nervous system that certain actions result which make up its life. There, you see, I have brought you to the verge of a somewhat difficult metaphysical problem. We ought all of us to have a proper appreciation of these things; if we had we should not be led into so many errors as we sometimes are.

You would probably like to know how the animal digests his food. Well, he does so very much in the same way as you and I do. In between his foot-jaws there is an opening, which is his mouth, and that opening leads into a short gullet, which gullet leads into a stomach, which is not below but in his back; so that if you wanted to hit him in the stomach you would have to get behind him. Then running along the whole of the back part of the body is a long intestine, and this animal is an example unique of an animal having an intestine no longer than itself. As a general rule, the length of the intestine of any animal greatly exceeds the length of the animal itself. For instance, the intestine of a man stretched out would be six times the height of his body. Some animals have a still greater length of digestive canal. The lobster has in his stomach a very complicated apparatus. It consists of a kind of mill, where, by the contraction of powerful muscles and the apparatus set in motion, the food taken into the stomach is very finely mixed. Then it passes into the intestine and is still further digested, and the blood-vessels absorb the nourishment. This apparatus is not of so high an order, but it is exactly similar to that which exists in our own bodies.

Then, again, perhaps you want to know whether our friend has a heart. Well, he has. I do not know whether it is susceptible to the same impressions as the human heart; but it is very near his stomach. Therefore, if it resembles the heart of any human being, it must be that of an alderman. This heart is situated just above the lobster's stomach. This said organ has a somewhat curious shape, and has a number of blood-vessels leading out of it. One goes upwards, and gives off branches to the eyes; then there is a pair going into the feelers; a pair going into the head and into the liver, which surrounds the stomach; and one long one runs all the way back to the tail behind. Blood goes into the veins, and finally gets back to the heart.

You know very well that if you or I did not breathe we should very soon get faint, then unconscious, and finally we should die. The lobster is like us in this respect; but inasmuch as we live above the water and the lobster underneath, it is necessary that his breathing organs should be of a somewhat different character. Underneath the carapace there are a number of organs which look like bottle-brushes; each one of these has a central stem, and a number of plumes. These litttle bottle-brush-looking affairs are what we call gills; the term "gill" being applied indiscriminately to those organs which exist for the purpose of getting the air out of water instead of directly from the atmosphere. The blood is taken to these gills, where it is brought into close proximity to the air in the water, and so gets purified by absorbing oxygen, in the same way that our blood gets purified in our lungs by absorbing oxygen from the air taken into them. Another curious fact is this, though some of these gills are attached to the lungs, not all of them are so attached, and the reason for this is doubtless as follows. You know that not only does the blood in the lungs get purified by the absorption of oxygen, it also gets rid of certain waste matters. Just in the same way the lobster's gills have waste to get rid of, as well as nutritious oxygen to absorb. The more a man works the more he wastes; just so with the lobster. Consequently, you see, that when he moves along very fast he is making a great deal of waste; the faster he moves the more he throws the water about, and the more water flows through the chamber in which the gills are contained, thereby more opportunities are furnished for the blood to get rid of its waste, and obtain vitalising material in its place.

A very beautiful arrangement is the one which obtains here for keeping a constant flow of water through the gill chamber, as the place is called where the gills are located. Just in the front part of this chamber there is a kind of swing door constantly working backwards and forwards; by so doing it keeps out the water from the front part of the chamber. The water comes in behind to supply the place of that which is let out in front, and by this baling-out process a constant current of water is sent through the gill chamber, and so the animal's blood is supplied with the oxygen which is extracted from the water, and its waste got rid of.

One other thing I must say something about, and that is as to how a lobster comes into existence. Eggs are laid by the female, passing by a small aperture at the second pair of walking limbs, and as they pass out they get cased with a somewhat sticky substance, which hardens in the air. These eggs thereby adhere to the swimmerets, each gives off a little stalk, and it is sometimes the case that a lady lobster swims about with something like two hundred of these eggs attached to her swimmerets.

The hatching of the lobster takes place while the eggs are attached to the lobster in the way I have described ; and when the little lobster is hatched, you certainly cannot say of it, what is so often said of the human infant, " How like his father " or " mother." He is not a bit like either, but appears to be a totally different animal. He comes out an ugly-looking creature with a tremendously large carapace, big staring eyes, and a little tail which has no joints in it. Then this hideous little object gradually develops into a lobster, and in doing so he changes his coat two or three times, and assumes the general shape and proportions of its parents. After the young are hatched, they remain for a time under the care of the mother, who seems to watch over them with a devotion not unlike the proverbial devotion of a hen for her chickens. As they come out of the egg the young ones swim about near the mother, who at the approach of danger seems to make some signal, at which they rush to their mother directly, and hold on to her swimmerets. We do not know what this signal is, but its effect may be frequently seen, as I have been told by a fishermen who had witnessed it. It seems that when the young ones who are floating about in the water near the mother are in danger of anything that is approaching towards them, the mother entices her little ones back to her protection, gets them attached to her tail, and swims away with them. After a while the little lobster, like the little man, gets tired of being tied to his mother's apron string, and so sets up business on his own account. He gradually grows until he gets to have some likeness to his parent, and from the fact that the number of cray-fish and lobsters seems to keep somewhere about the same, it seems probable that the birth-rate does not greatly exceed the death-rate ; there is no registrar of deaths for lobsters, but this seems to be the case.

And now, I think we have got some good digestible mental food from somewhat indigestible physical food, because lobsters are not very digestible, especially if eaten at night, when they are provocative of nightmare. I should like, before leaving the subject, just to say a word or two about the eye of the lobster.

I told you that the lobster possessed organs of sense, although we do not know whether there is any actual consciousness of vision or hearing. The eye of the lobster is a most interesting structure, and I will endeavour to make it clear. That little object which you see hidden under the spine of the lobster consists of a number of small facets; each one of these has attached to it a crystalline body of a somewhat triangular shape. That body opens into a long rod, and that rod again into a somewhat spindle-shaped body; that is to say, a body which is bigger in the middle than at the ends. This is very finely striped. Then the optic nerve comes from the first lump of nervous matter, often called the brain. On the top of that there is a kind of band or brush, and the spindle-shaped body comes into contact with that brush so that, in some way or other, the rays of light affect these structures and pass on the undulations or vibrations to the optic nerve, which conveys them to the brain, or to the lump of nervous matter which answers to the brain. This structure, I may tell you, is very much like what an eye would be like if you took all the front part away. In the human eye there is, first of all, the pupil opening in the coloured part; and behind that a double convex lens, very much like the spectacle glasses which people wear when they get advanced in years. There is also a quantity of matter in the eye of jelly-like consistency, which assists in bringing the rays of light to a focus upon the delicate screen which is connected with the optic nerve. In that screen you have some rodlike bodies, and some bodies, also, which are called cones, and these bodies undoubtedly play an important part, similar to the part played by the cones, rods, and spindles in the lobster's eye. With regard to the lobster's hearing powers, there is in the basal or bottom joint of the feelers a small *sac*, which *sac* has a rent across it, on which are a number of fine hairs. It contains a small quantity of fluid, in which you have a number of sandy particles. The same thing exists in that which is, perhaps, the most perfect structure in the human body, the ear, only it is somewhat more elaborate. The essentials of the sense of hearing, however, in the human subject are just the same as they are in the lobster. The fluid contained in the *sac*-like cavity, which fluid contains a number of hairs, and a number of sandy particles; then we have in addition, of course, certain important structures in the human ear which are wanting in the lobster.

I have dwelt somewhat at length upon the character of the lobster in its structure and its physiology, as we call it, because it is a type of a very large number of animals whose bodies have not backbones—such animals I mentioned in the early part of my lecture; and we find also that the lobster can trace his family history back far beyond the grandest genealogical tree of any human being who ever existed—far, far back in the history of creation, right to its very dawn. Representatives of the class of animals to which the lobster belongs you find in almost the oldest rocks—animals which are called *trilobites*, because their bodies are divided into three lobes, and these animals were undoubtedly animals of the same kind as the lobster. We have also been able to discover, in one instance, a number of these animals in various stages of development, right from the little creature just born to the grandfather, and the whole series has the same character which distinguishes the lobster of the present day. You see, thus, that the lobster is a creature of considerable interest; and the study of so simple a thing as this animal, which we see, in connection with his cousin the crab, upon almost every fishmonger's board, leads us to the consideration of problems which are of the very highest moment and the deepest importance; and I think that in dwelling for a little while upon this page of natural history connected with the lobster, your attention will not have been wasted.

XIII.

THE COMMON FROG.

UPON my journey here this evening, watching the beautiful sunset, my thoughts were turned, as they so often have been before, to the contemplation of this beautiful world in which we live. Saddened as we so often are, by man's handiwork, we are always cheered and refreshed when we turn to that which comes from the hand of God, and we find, in even the meanest of His works, something to wonder at, something to admire. The little animal which I have chosen for the topic of my lecture on this occasion is no exception to that general rule, and I feel sure that we shall not waste time, whether we be poor cockneys who have never seen a frog, or people who in their early days were very familiar with them, in considering for a short time the history of the common frog.

You will remember that some time ago, I spoke to you here about another very common animal, the lobster, and I pointed out that that animal was a representative of those who have no backbone, and are therefore called by learned men, *invertebrated;* the animal which we are now going to speak about occupies a very much higher position in the scale of life, inasmuch as he is by no means the lowest of those animals which, like ourselves, do possess a backbone, and are, therefore, termed *vertebrated.* Several other important differences between this animal and the lobster we shall come to presently.

First of all, allow me to introduce to you the frog himself, and, by-the-bye, I may say at once that he is more likely to be frightened by you, than you have any right to be frightened by him. I want to point out to you, first of all, the general structure of the frog; and you notice that, like ourselves, the frog has a head and trunk and two pairs of limbs. As he has no necessity to wear a collar, his head is not joined to the trunk by a neck, but seems to be almost a part of it. You will notice also that he has a mouth, which literally extends from ear to ear, and it is no exaggeration to say that when a frog opens his mouth his head is half off.

Those two brown spots, one on each side just behind the eyes, are his ears; he has nothing at all corresponding to the *pullable* part of the ear, with which we are adorned; in fact, the ear of the frog consists merely of the actual essentials of the organ of hearing, without that external part which in four-footed donkeys attains such an enormous size. This brown ring is nothing less than the drum membrane of the ear, and on the inside of that is a little bone which answers to three bones which we have in our ears. Through that bone the movements of the ear, the vibrations of the drum membrane, are communicated to the internal ear, which is a very complicated structure indeed, in which the small endings of the nerves of hearing lie, and which are thus affected, and convey something, probably motion, to the brain which translates that into what we know as hearing. You see by this that, just as in ourselves, the frog does not really hear with its ears, but with its brain—an important piece of natural knowledge which we are all apt sometimes to forget.

It is a very convenient thing to say that we "hear with our ears," and that we see with our eyes, and smell with our noses, but these statements are not accurately correct. If we had no brain, no matter what takes place in these organs of the senses we should have none of those special perceptions which we call special senses. The brain is the seat of all feeling and of all sensation—the only seat—and it is in consequence of certain vibrations which are transmitted by these organs to the brain that we possess those wonderful senses which bring us in relation to the outer world, and are the sources of so much pleasure and instruction.

Coming to consider the limbs of the frog, we notice that there are, as I have said, two pairs, and in that respect resemble our own; but I am quite sure that no one here would boast of possessing legs which are so dreadfully unproportionate in length to the forelimbs. The arms, as we may call them, of the frog are certainly very short, and whatever else may pass between the frog to whom he goes a wooing, there would not be much clasping of waists. You will notice, further, that his hands have upon them four slender fingers, and you may sometimes come across elementary text books which profess to tell you all about the frog, which they do, and a great deal more, for they describe it very accurately indeed, some going so far as to describe the frog's finger-nails and toe-nails. The difficulty is, however, that the frog does not happen to have any nails at all, which is decidedly inconvenient. There are four fingers, then, upon the hands of the frog, instead of five as with ourselves.

You may like to know a ready means of telling the male from the female frog. In the female, what answers to the ball of the thumb is like the rest of the hand, quite pale and thin, but in the male frog the part answering to the ball of the thumb is very hard and compact, very much like a black corn which wants cutting very badly. Then taking into consideration the hind legs, we find that they are, comparatively speaking, very long, and it is by reason of possessing these very long legs that the frog is able to execute those leaping movements which so greatly alarm our fair friends when they are walking in Epping Forest, Richmond Park, or some other suburban retreat. You see that, just like our legs, those of the frog really consist of three parts, a thigh, leg, and foot, including an ankle, and if the foot of the frog is very long and flat, it is simply because it has a very long ankle, and that the joint between the foot and the leg is above instead of below the ankle, the foot, therefore, spreading out very much. You will notice, further, that the frog has five toes, although he has only four fingers, and whereas his fingers are quite disconnected with each other, his toes are connected together by a very delicate web, which web is so fine that under the microscope you can see what is perhaps the most wonderful sight it is possible for human eyes to behold, the actual circulation of the blood in the frog's foot.

The skin of the frog is, as you know, spotted, and has a somewhat brown or brownish yellow groundwork, the spots being usually black. The skin of the frog has some property analogous to that of the chameleon, which, as you know, can, or does, change its colour, the skin of the frog being light or dark according to circumstances, being largely affected by the amount of light to which it is exposed. You, of course, remember the old tale of the chameleon, which in this respect is very remarkable. You know the story goes that two travellers met and began to exchange anecdotes. Traveller's anecdotes are not always very reliable, and these two men frequently came to high words, for they began to speak about the chameleon. One said what a beautiful blue skin it had. "Oh, no," said the other, "that is wrong; it is not blue, it is green!" Then from words they came almost to blows, until presently a third traveller came up, and in order to settle the matter in dispute, they agreed to appeal to him as as arbitrator. He differed from both, and said the animal was black, and so made matters worse, but the third traveller happens to have with him a chameleon, and so, to settle the dispute, he says, "I have one with me, and will show you that I am right." He produces it, and it turns out to be white! So they were all considerably mystified, because they did not know what we do—that the chameleon's skin changes in colour under different circumstances, probably of the nervous system.

These are the principal features in the exterior of the frog. And now I want to point out to you a few facts connected with his internal structure, and also with the way in which he lives. You will remember, of course, that when we spoke of the lobster, I pointed out to you the fact that it was just as necessary for the lobster to breathe as it is for a man, and so, indeed, we may say of every animal with which we come in contact; breathing in some form or other is an absolute essential of life, and the object of breathing is the same throughout the animal creation, viz., the purification of the blood. Every one of us, and every animal also, is constantly using up the nutritious materials in the blood, constantly impoverishing it thereby, and is constantly adding to the blood waste materials which also render it impure. In fact, if we look on one side only of its functions, which is to carry away from all the tissues of the body the waste materials, the blood may be looked upon as the great sewage system, and one place where the waste materials are largely got rid of is the breathing place, whatever that may be. In the lobster, and in all animals which live in the water, the breathing apparatus consists of what we call gills, which are simply structures so arranged as to be capable of extracting the air from water. In the higher animals, such as ourselves, and our friend the frog, the apparatus for breathing consists of what we call lungs, and these lungs are simply pieces of apparatus for extracting oxygen—the life-giving element—from the air, and not from the air which is always dissolved in water.

The frog possesses lungs, and we find that the frog is always very busy taking in air and getting rid of it, and if you watch our specimen here you can see him at work. If you notice the baby when you get home, if you have one, or somebody else's, when it is asleep, you notice that the action of the baby's chest is very pronounced, and the whole act of breathing differs considerably from that of the frog. In ourselves and in the baby, whether it is asleep or awake, you see that gradual rhythmical rising and falling of the chest, as air is taken in and given out, but in the frog you see he is constantly swallowing. If you did not know any better, you would think he was listening with apparent wisdom and swallowing the lecture; but he isn't. I daresay, if he were capable of thinking at all, he would think thus—"I know a great deal more about myself than you do, and, therefore, I can learn but little from it." In the case of the frog, however, every mouthful of air is actually swallowed. The frog closes his mouth, draws air in through his nostrils; then at the back of the nostrils there is a little flap, which acts as a valve and closes the aperture through which air has just come; then with the mouth still closed, the frog makes a gulp, and down goes the air into his lungs. The lungs do not move at all, nor do the chest walls, except in that very slight way in which they move in ourselves when we swallow anything. In the case of the frog there is an actual swallowing of air, and in that way air gets into the lungs, but in our own bodies there is a kind of pump at work, which is constantly pumping air in and out of the lungs.

Arrived in the lungs, the changes which take place there in the frog are just the same as those which take place in every other animal, including ourselves. The pure air gives up to the blood oxygen, which the blood needs for its purification, and the blood gives up to the air a poisonous gas known as carbonic acid gas, which it wants to get rid of, and that is carried away with the air which is expelled or breathed out. Just the same need exists in the case of the frog, although the means by which that need is supplied differ somewhat in ourselves and in the frog. And here is a lesson that we may learn from this humble animal.

Some people do not believe in fresh air. You find them blocking up the chimneys of their bedrooms, stopping up the cracks of the doors, and doing everything to shut out fresh air and keep in that which is in the apartment. Do you know what happens when you set to work to stop up every possible chink you can find? The fire goes out; and just as surely as you can put out a fire by stopping the access of fresh air, so surely can you damage, if not altogether cause life to cease by shutting out fresh air. Never shut out more fresh air than you can possibly help. In this crowded city it is little enough we can get; let us get all we can.

Then there is another folly we can learn to avoid by looking at the frog. You see that the frog has not that particular wasp-like waist which ladies seem so very fond of —or at least some of them. He has not that beautiful "figure" which some people profess so much to admire, but he is thoroughly healthy, and breathes more comfortably than can those ladies who lace themselves so tightly. Depend upon it there is no more pernicious habit in this generation than that of tight-lacing. If you watch anybody in the act of breathing, what do you see? You see that, especially in the female, the chest is constantly rising and falling with every breath. These movements which you see are simply the movements of the respiratory pump, and in order that life may be thoroughly fresh and vigorous, and in order that you and your children may be well and grow up strong and healthy, it is above all things necessary that you should give the respiratory pump plenty of room to work properly. Twenty-five centuries ago a Greek poet told the Athenians that "No ordinance of man can override the settled laws of nature and of God," and although twenty-five centuries have rolled away since those words rang out in Athenian ears, they are just as true in this nineteenth century as they were when they were first uttered.

In addition to breathing by the lungs, the frog breathes to a large extent by his skin, and that is why you can always keep a frog a long time if you keep his skin moist. In our own case, the blood is taken from the heart to the lungs, and to the lungs only, to be purified; in the lobster, you remember, blood was taken to the gills to be purified; but in the frog the blood is taken to the lungs and also to the skin to undergo the process.

Our frog has been under a glass for a few moments, and the glass is covered with moisture. This is the same thing that happens when we are in rooms which are imperfectly ventilated. You shut up every window, and you very soon impoverish the air: the room gets full of moisture, which condenses on the cool glass. We perceive that our frog was becoming inconvenienced by his close confinement, and if we had allowed him to stay there much longer it would have been an act of cruelty, for probably he would have been suffocated; and although you may often be in a room where you do not experience a sense of suffocation, you may often go a part of the road towards it and get a bad headache. You may shorten your life, or render so much of your life remaining to you far less worth living than it might have been, by neglecting to have good ventilation. By ventilation I do not mean necessarily draughts. I wish somebody would settle some means of getting thorough ventilation without draughts; but although our knowledge of the principle of ventilation is very imperfect, still we can, if we choose, devise many means in our own homes for getting fresh air without injurious draughts, which give us cold.

The next important thing that we have to notice in the frog is the way in which this purification of the blood benefits the system generally. I said just now that the object in the blood being taken to the lungs was that it might be purified, and I also remarked that the blood system was very much like a great sewage system, carrying off all the waste of the body. But besides that, the blood plays a very important part in carrying nutriment to all the tissues, and from the same fluid into which it pours its waste material, each part of the body can take out the special nutriment which it requires. In addition to these two important functions, the blood system also performs the part of a hot water apparatus to keep the body warm. All these three functions render it necessary that the blood should be kept in constant circulation. Let us, then, for a few minutes, look at the wonderful organs of circulation in the frog, and let us notice the differences in that circulation between the frog and ourselves.

You all know that you may possess a heart. You may have lost it, figuratively speaking, at some time or other, but still you know that you have a certain pump which is constantly going pit-a-pat, sometimes faster than at others, within your breasts. We know, in a general way, that the heart has something to do with the blood, but perhaps we do not know the exact part which it plays. Now, the heart is the great force-pump, and that beat which you hear and feel at the chest is simply the constant rhythmical working of that force-pump, pumping blood into and out of the heart, and sending it to and fro all over the system. Connected with the heart you have two sets of pipes, one set carrying the blood away from the heart, and the other bringing it back to the heart, while both sets are joined by some very fine hairlike tubes which come between the two. You know that in a tree the main branch constantly gives off smaller branches, which latter give off branches smaller still, and so by constant growth and subdivision from one branch you have an immense number of smaller branches formed, terminating in little tiny twigs. Just in the same way the vessels leading from the heart branch off and get smaller as they branch off, until at last they pass into tiny little vessels so fine that something like 3500 of them could lie side by side in the space of an inch. In just the same way as the tubes which lead *from* the heart branch out into numberless smaller vessels, so do the vessels which bring blood to the heart, as you follow them from the heart, branch out into finer and finer vessels, and if you can imagine the branches of two adjacent trees becoming united by their terminal twigs, you have a very fair notion of the way in which these two sets of tubes are united in one continuous system. In the blood system of the frog, as also in ourselves, you have in the centre a heart, and then a set of vessels going from the heart, branching off into finer and finer tubes, and another set of vessels, which bring blood back again, also branching off into extremely fine vessels, in which very fine vessels the junction between the two sets is affected.

As our heart is, perhaps, physically speaking, better understood than the heart of a frog, let us see what sort of arrangement we have there. The human heart is divided completely into two parts inside, by a partition which runs down from the broad part nearly, but not quite, to the pointed end, and between the two sides there is no direct communication whatever; the blood can only get from the right side to the left by going through the blood vessels; it connot get through this partition. Each side of the heart is divided into two chambers, each connected the one with the other. The top chambers receive the blood, and are termed *auricles*, while the lower chambers discharge the blood and are called *ventricles*. Into the receiving chambers upon the right side you have blood coming from all parts of the system, and that blood is impure and dark in colour, not dark because it is dirty, but simply because the matter which colours it is of a different kind to the matter which colours the pure blood; it contains, in fact, less oxygen. The blood passes from the upper into the lower chamber, and then from the lower chamber it passes out by another vessel into the lungs. In the lungs the blood is exposed to the air which gets in, as you know, down the windpipe, and the air must be fresh and pure, or how can it purify this impure blood? In the lungs, then, the blood gets in actual communication with the air. Just as air will pass through a moist piece of skin, so air will pass through the thin walls of these little tiny blood vessels of which I was speaking just now, and into these little hair-like twigs oxygen finds its way and purifies the blood. Through these tiny vessels also the carbonic acid gas passes out into the air, so that the air which goes into the lungs gets impure by purifying the blood; and it is constantly pumped out again by this respiratory pump, in order that fresh air may be taken in to carry on the same work as before. The pure blood then comes back from the lungs, and gets from the lungs into the left side, going into the top chamber and then passing down into the bottom chamber, goes out from thence into one of the large tubes which bends over in a kind of arch, and which runs down just in front of the backbone. It then goes off into innumerable branches. These go to the bottom of the trunk, branching off into two big branches, one for each leg, and then again branching off into numerous smaller branches, supplying the various parts of the legs right to the extremities of the toes. The head is supplied by two vessels which run up on either side of the neck, giving off as they go along branches for the upper extremities of the arms. So you see there is a complete set of tubes for carrying the blood all over the body, and as I have already said, the further they are away from the heart the blood vessels get smaller, but much more numerous, and at last they pass into little tiny twig-like vessels; from these proceed the vessels very similarly disposed, which carry the blood back again to the heart.

Now you see what a wonderful process is this which we call the circulation of the blood. The heart beats in an ordinary adult at the rate of sixty-five to seventy-five times in a minute, and at each beat there is, first of all, a dilation, or swelling of the heart, as the blood pours into it. Then comes a sudden contraction, not unlike the sudden squeezing up of a sponge, which squeeze pumps the blood out into the blood vessels, sending some of it into the lungs and the rest all over the body. That which gets into the lungs goes from the right side, that which goes over the body goes from the left side, and so you see in the human heart there is adequate provision for the purifying of the blood, and sending it all over the body to restore and nourish it.

In the frog there is not quite so complete an arrangement. The partition, which in the human subject extends right from the base of the heart to near the pointed end is in the frog incomplete, so that, while the upper part of the heart is divided into two chambers, the lower part consists of only one. There are in the frog two receiving chambers, and only one discharging chamber, and you can easily see that the blood on the right side being, just as in the human subject, impure blood, and that on the left side pure, there must, to a certain extent, be a mixing of the two kinds of blood in the one discharging chamber. Nature, by a very complicated arrangement of a kind of swing door, and by a difference of pressure in the blood vessels in the head, legs, and body generally, has supplied this apparent want of perfection in the machinery. The best blood of the frog thereby goes to nourish the brain and head generally, the next best is sent all over the body to nourish the least important parts, while the impure blood is, much as in ourselves, sent to the lungs and skin to be purified. In this way we have in the frog adequate provision made, not only for the purification of the blood, but also for the proper distribution of that blood over the system.

I said a few minutes ago that the circulatory system acted as a system of hot water pipes. Let us see how this is brought about. When a candle burns, or when a gas jet is alight, or when a fire is burning, there is a union of oxygen with certain materials in the candle, gas, or coal. We have in the body, oxygen in the blood, in the lungs, and in the tissues generally, oxygen being taken from the blood and uniting with the tissues. Now it does not matter whether you light a match, or whether you burn a ton of coals at a time, both of those would give you flame and heat; the only difference is one in quantity, not in kind. Just in the same way, that which is constantly going on in our own bodies when oxygen unites with the blood, or when the oxygen in the blood unites with the body, is simply *burning;* not burning, of course, to such an extent as that which you find in the gas flame or in the fire, but burning, or combustion, nevertheless. If you burn a ton of coals it doesn't matter, as far as the amount of heat you get from them is concerned, whether you make a big bonfire of them or burn them a shovelful at a time; the process is the same, and so, although the combustion which is going on in our bodies is slow combustion, it is, nevertheless, just the same in kind, and also, proportionally, in quantity, as that which we behold in our fire, gas, and candle flame.

Of course, while this combustion is going on heat is produced, and the blood is warmed, and as the heart is constantly pumping this warm fluid all over the body, the latter is kept warm; not hot in one place and cold in another, but equally warm in every part, just in the same way as a large building is warmed by hot water pipes, which, as you know, are connected with a stove from which the water starts, and to which it is returned to be rewarmed.

Having such an arrangement as this in our system, we want, of course, some means of regulating it, and we find that this exists in the skin. When the weather is very hot, or when we have been working very hard, and also when the weather is close, muggy, and damp, you know that our skin gives off a quantity of moisture which we call perspiration, or sweat. That perspiration is also waste material, but it serves another very important function, and that is, the regulation of the animal heat. When our bodies are very hot, and the action of the heart is required to be reduced by a function of the nervous system, the blood vessels of the skin are put on the stretch, they extend a little, and more blood than usual comes to the surface of the body. When that blood is only separated from the air by the skin, which is a comparatively thin membrane, some of the water of the blood is, as we should say, dried up, or evaporated, and whenever you dry up anything you must have heat used in the process. If you allow a drop of spirit to fall on your hand it feels cold ; the reason of the chill is that in order to turn the drop of spirit into vapour and so disappear in the atmosphere, heat is required ; this heat is taken from the hand by the spirit, which, as you know, very rapidly evaporates. In the same way, when we perspire freely, in order that the watery perspiration may be turned into vapour, dried up, and caused to disappear in the air, heat is required ; that heat is abstracted from the body, and thus it is that we are cooled by perspiration.

In cold weather, on a sharp frosty day, the skin is dry ; then the blood vessels have shrunk a little, and less blood than usual is going through the vessels of the skin ; less evaporation is going on, less cooling is taking place. Therefore we can understand that in the skin we have not only a wonderful apparatus for removing some of the waste of the body, but also for regulating the body's heat, and this is as true with regard to the frog as it is with regard to ourselves, except that in the frog there is also a function performed by the skin which is very much like breathing. The frog's skin is always more or less moist, and through it, to a certain extent, the frog breathes—his blood obtains oxygen from the air by means of the blood vessels of the skin, and gets purified there as well as in the lungs.

If you are not quite tired, I should like to say a word or two more about the blood, for it is such a wonderful fluid. You know, of course, that if we want to keep ourselves in good health, to keep up our strength, and prolong our lives, we must have plenty of wholesome food. Just so is it with the frog; he is a most active hunter, and if you happen to have a garden, you cannot do better than keep a frog on the premises. He costs nothing to keep, he will be of great service to you, inasmuch as his food consists largely of insects. Insects, you know, are bad gardeners, and the frog when he sees an insect, as the Yankee says, "goes for him" and "fetches him," then he devours that insect, or insects, and he is satisfied and you are pleased; therefore, I say by all means keep a frog if you have a garden. Well, then, the nutritious matter which the frog takes as food passes into his stomach. His stomach is covered with blood vessels, just in the same way as our own. These blood vessels take up the nutriment from the contents of the stomach into the blood; so the blood gets nourished as well as purified, and as it goes over the body the latter not only gets rid of its waste in the manner in which I have described, but it also takes out of the blood just what it requires for its nutrition. I think there is no more wonderful fact in Nature, than this—that although our bodies, and the body of the frog, too, comprise such different structures as bone, muscle, skin, liver, lungs, &c., each one of these and the various tissues should have the power of taking out of the same fluid, just the very material which it wants to build itself up anew. That is to me one of the most surprising and wonderful phenomena which the whole realm of Nature offers for contemplation.

You would like, perhaps, to know how the frog grows. The natural result, of course, of a frog going a-wooing would, in the long run, be that he would have a numerous progeny. Well, now, a frog's progeny, when it first appears is a very curious brood. If you go to any of our ponds in the spring of the year you will find, if you look carefully, masses of somewhat glutinous, jelly-like consistency, floating upon the surface. If you take it up and look at it carefully, especially if you have a lens through which to examine it, you will see that this mass contains a number of black spots. These glutinous masses are simply the frog's spawn, masses, that is, of egg, joined together, and left there by Mrs Frog to hatch. In course of time the hatching takes place, and there comes out an extremely small animal, which is not much more like a frog than a mackerel.

The frog, you know, has no tail, and you know further, that the frog lives on insects, and also that he breathes by means of lungs, and though capable of living both in water and on land, he usually passes most of his time on the land. The little frog, however, lives entirely on vegetable food, has a very long tail, has gills instead of lungs, and lives in the water, and is to all intents and purposes a fish. Such an animal, then, is the tadpole, or young frog. He has a somewhat fat little body, with a very long tail. Human mammas have babies without tails, but they make them very long tails when they dress them in long clothes, but Mamma Frog has no such necessity. The mouth of the little tadpole is much more elegant than his mamma's, inasmuch as it is a comparatively small one, instead of being a huge slit from ear to ear.

First of all, the tadpole has no limbs, but has on each side little outgrowths which are external gills, in which the blood is purified, just as in the gills of a fish. After a time, when the tadpole gets older, the gills begin to disappear, but before they completely do so you see little buds grow on each side of the body of the tadpole, two near his tail, and two just under the gills. These are the rudiments of the limbs of the future frog. Gradually the gills altogether disappear, and then a plate of skin grows over the clefts or slits in the frog's throat which formerly existed. These slits close up, the gills disappear, lungs are developed, and the tadpole gradually ceases to be a water breather and becomes an air breather; it ceases to have its blood purified by means of gills. Meanwhile the limbs are growing, and they gradually develop into such a structure as that which we see in the full-grown frog. As this takes place the tail is gradually absorbed, and eventually you have an animal without a tail, though we have made rather a long one of it to-night.

I told you that the frog lives on insects, whereas the tadpole lives on vegetables. That necessitates some change in the digestive apparatus of the young tadpole. When the animal lives on vegetable food its digestive canal is very much longer than when it lives upon animal food, and consequently the little tadpole has, in proportion to its size, a much larger intestine than the adult frog. In the tadpole the intestine is coiled up like a watch spring, so as to get plenty of it in a small space, but as it grows the intestines grow also, but not nearly so fast as the body of the tadpole. and the watch spring arrangement is somewhat loosened, In the full-grown frog the intestinal canal is by no means a very long one. So you see that going on, step by step, with these external changes there are also internal changes which render the young tadpole more fit for that position in life in which he will shortly find himself. At the same time, his mouth is altered in shape and character, and the development of his tongue is completed. The tongue of the frog is a very curious thing. Our tongues are fastened at the back, at the root, so that the top is free; if it were not so we should not be able to wag it so much as we do. In the frog the tongue is attached at the top, and he thrusts it out in such a manner as to catch insects. When he gets them on his tongue, back it goes, and the prey is swallowed. Their temerity in getting upon the frog's tongue is followed by an early death.

And now, I think, we must end our talk about the frog. As I told you, it is only a small portion of the wonderfully interesting history which we might extract from such a simple animal as this, but one lesson, however, I think we may learn, and that is, never to despise any object, however insignificant it may seem; never to call anything ugly because we cannot at first sight see it to be beautiful. Nothing that God has made deserves the epithet "ugly," however loathsome or repulsive it may seem at first sight to appear; because we are too ignorant, or, perhaps, too blind, or because we want the training to see the wisdom and admire the beauty, it by no means follows that these objects of admiration are not present.

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